Arthur Mead Edwards.
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THE

PRINCIPLES OF BOTANY,

AS EXEMPLIFIED IN THE

PHANEROGAMIA.

BY

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DEDICATED

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PART IV.

PREFACE.

THIS volume renders complete the previously published work of the author entitled, "Principles of Botany as exemplified in the Cryptogamia." In that work it was shown that the same laws of nutrition and reproduction operate in the vital economy of plants composed of a few cells as when vegetation is constructed on a scale of gigantic magnitude and grandeur. In this new volume on the Phanerogamia or flowering plants, the author enters on the investigation of the anatomy and functions of a more highly organized and complex vegetation. He has examined with care, the writings of Schleiden, Lindley, Balfour, Gray, Richard, and other eminent botanists, but above all the Volume of Creation, of which every other work is but an imperfect copy. The book is illustrated with numerous engravings, and such scientific terms as it was necessary to introduce into the text have been carefully explained and their etymology given as soon as introduced.

The author takes this opportunity of gratefully acknowledging the kindness and liberality of the physicians of Philadelphia, who have been and still are his principal patrons.

He has written this volume on the organography and physiology of the Phanerogamia, in the hope that it will be generally useful, but with an especial reference to the wants of medical students and physicians: life probably exists under the simplest and least complicated condition in plants.

The author ventures to hope that this volume, (which he has been encouraged to prepare,) will be found equally as interesting as the one already published, and contain such an amount of original and well-selected matter as will render it worthy of that liberal patronage which has been bestowed on his previous labors.

INTRODUCTION.

PLANTS exercise, in common with animals, the two principal functions of organic life—nutrition and reproduction. All the organs of the most complex, as well as of the most simple plants, are developed for the purpose of carrying on one or the other of these two functions.

The tissues which constitute the substance of both animals and plants are formed from cells, and exhibit a most remarkable accordance in their vital phenomena. In both, peculiar secretions are carried on, which are restricted to certain parts of the organism; whilst as life advances to the period of its close, the walls of the fully developed cells become thickened by the internal deposition of matter in layers. Ossification in animals exactly corresponds to lignification in plants.

Plants as well as animals reproduce themselves. Flower-bearing plants when they arrive at an adult state develope male and female organs, termed stamens and pistils. These mutually operate in the formation of an embryo or seed, which contains within its folds, in a rudimentary condition, all the organs of the fully developed plant. These embryos are formed in a particular organ termed an ovule, and are developed in consequence of imbibing the fecundating matter of certain cells termed pollen. Thus, from the vital actions of

plants, there may be much instruction derived, which will be found a valuable contribution to our knowledge of the reproductive function in more highly organized beings.

In the animal organism, the nutritive and reproductive functions are greatly complicated by the presence of a nervous system. In plants, these two grand functions of organic life are carried on free from nervous influences, and therefore under greatly simplified conditions. The careful study of these functions, thus simplified in plants, ought therefore to precede the investigation of their higher and more complicated phenomena as manifested in animals.

It is undeniable that the plant takes precedence of the animal in nature, being elaborated out of inorganic matter as material for the subsistence of the animal. It would therefore seem to be the most natural and philosophical mode of investigating the phenomena of life, first of all, to see to what extent its functions have been expressed in plants.

All organic matter appears to be only a manifestation of life in different degrees of development, and a plant may be truly regarded as the simplest manifestation of its functions.

In the author's "Principles of Botany, as exemplified in the Cryptogamia," it was shown in sections 50, 51, that the simplest plant in nature is the plant cell, which "constitutes an entire vegetable without organs, imbibing its food by endosmosis through every part of its surface, which it converts into the materials of its own enlargement and growth, and finally into new cells, which constitute its progeny." But as we advance in the scale of organization, the cells thus generated do not separate from the parent plant cell; on the contrary, they remain united with it, to a greater or less extent, until we find individual plants composed of a mass of such cells, all mutually

co-operating in carrying on the nutritive and reproductive functions. It was also there proved (54–57), that "it is not necessary for cell-development to be carried to any great extent in order to constitute the fabric of a true and perfect plant;" on the contrary, the same laws of nutrition and reproduction operate in the vital economy of plants composed of a few cells as when vegetation is constructed on a scale of gigantic magnitude and grandeur. In such plants, it is evident that we have the phenomena of life existing under extremely simplified conditions; and if ever "man, the minister and interpreter of nature," is destined to discover those morphological laws which govern this evolution and endless repetition of the same definite forms of vegetable and animal life from the same embryos, it is here that he must commence his investigations.

Hitherto the attention of the student has been directed to the consideration of cryptogamous vegetation, we are now about to enter on the examination of vegetable life as unfolded in the more complex and elaborate organization of the Phanerogamia, or flowering plants.

In the lower forms of the Cryptogamia the essential organs of vegetation, the root, stem and leaves, are blended together into a flat or filamentous expansion of vegetable matter, termed a thallus, from whence these plants have received the name of thallophytes (θαλλὸς a frond, φυτὸν a plant.) These plants have no vegetable axis or stem, and increase by additions of matter to their periphery or circumference. They have a tendency to grow in a horizontal rather than in a vertical plane, their spores germinating indifferently in all directions from any part of their surface.

The cells which constitute the tissue of thallophytes, in the lower forms of their development, appear to retain the form,

and to exercise the functions of the parent plant cell, with which they remain permanently united. Thus, in the numerous tribes of marine Cryptogamia or algæ, the endochrome (ἔνδον within, and χρωμα a color) is diffused through the entire substance of the frond, so that the whole plant presents the same color in all its parts, and the reproductive matter, or sporules, makes its appearance in many species, indifferently on any or every part of the plant.

In the Phanerogamia, or flowering plants, on the other hand, root, stem and leaves are separate, well-defined organs. From the first commencement of germination there is a stem more or less manifest, and a tendency to develope in two opposite directions, into the earth and atmosphere, the two grand sources from whence these plants obtain the materials of their growth or enlargement. To subserve the purposes of a higher and more elaborate nutrition, certain cells of the parenchyma are carried to a much higher degree of development, and assume the form of woody fibre and spiral vessels.

The pleurenchyma of flowering plants (26) becomes more distinctly marked in their leaves, as organization advances in complexity of structure, until at length, in the most highly organized plants, its fibres form a beautiful anastomosis of veins, veinlets and capillaries. The leaves of Thalictrum anemonoides, the rue-leaved anemone, an early and exceedingly abundant spring flower, furnish an admirable illustration of pleurenchyma thus ramified and attenuated.

But throughout organic nature, a change in the form of any organ is always associated with a corresponding change in its function. The secretion of the cells is therefore no longer uniform, but varied and well defined in its character, certain

peculiar secretions being restricted or confined to certain portions of the organism.

The analogy between the vegetable and animal tissues is beautifully apparent in the secretory action of the cells of phanerogamous plants. The same endochrome, or coloring matter, no longer gives an uniformity of hue to the tissues, but the leaves which terminate the axis of growth become crowded together into a beautiful rosette at its summit, and secrete a variously colored endochrome, which has received the name of chromule (χρωμα color), in contradistinction to chlorophyl (χλωρὸς green, φυλλον leaf), which is the substance which gives to the leaves their green hues.

But the possession of a terminal rosette of beautifully colored leaves, popularly called the flower, is by no means the principal characteristic of Phanerogamous vegetation, since in some flowering plants, as for instance in the grasses, these colored investments become abortive and rudimentary. Yet the organs essential to the formation of the embryo are there, the stamens and pistils, and it is the presence of these bodies which constitute the true flower.

The difference between phanerogamous and cryptogamous plants consists in the possession by the former of stamens and pistils, or true flowers, (of which the latter are wholly deprived,) by the mutual action of which an embryo or seed is produced, which is a much more highly organized body than the spore. The spore from which every cryptogam is developed is commonly a simple cell filled with organic matter, and the organs which it developes in germination form themselves as they appear; but in the embryo or seed, these organs existed before, and are only increased by the act of germination. The character of an embryo in organic beings is, that it contains, in a rudimentary

state, all the organs of which the organic being is composed in its entire developments. Thus the animal embryo consists of the head, the trunk, and the extremities,—in other words, of all the parts of which the adult animal is composed. In like manner, the embryo of a phanerogamous plant, of a bean for example, discloses a plumule or young stem, a pair of leaves or cotyledons, and a radicle or young root,—in other words, the entire plant in a rudimentary condition; and by the act of germination, analogous in its effects to the commencement of life in infancy, all the parts of the plant develope themselves into their wonted figure and hues in accordance with those generic and specific laws to which the plant is subject; but germination does not increase the number of these parts, which existed before its influence was exercised on them.

PART III.

ON THE

COMPOUND ORGANS OF PLANTS.

THE PHANEROGAMIA, OR FLOWERING PLANTS.

PART III.

ON THE ORGANS OF NUTRITION IN PHANEROGAMOUS PLANTS.

VEGETATION, in the more highly organized and complex forms which it assumes in flowering plants, consists essentially of a continuous axis or trunk, which developes in two opposite directions, and is more or less ramified at its two extremities. The superior or ascending portion of this vegetable axis is called the stem, the inferior or descending portion the root, and the point of departure of either axis the collet or neck. This neck is usually distinctly visible when the embryo plant first rises from the ground; after the cotyledons, or first pair of young leaves, have developed, it disappears, and becomes a merely imaginary line of separation between the base of the stem and the root.

These two extremities of the vegetable axis are beautifully adapted to the earth and atmosphere, the two grand sources of all vegetable nutrition. The aerial portion of the plant is provided with leaves, by which food is taken in from the atmosphere, and also with flowers, which are the organs of reproduction; the subterranean portion is furnished with a quantity of fibres or smaller roots, which make their appearance in proportion to the requirements of the plant and the barren or fertile nature of the soil in which it grows. This vegetable

axis, with its assemblage of nutritive and reproductive organs at its two extremities, has been very properly termed the axophyte.

Before commencing our exposition of the anatomy and functions of the fundamental organs of flowering plants, it is proper to examine that peculiar investment which covers them, termed the epidermis.

CHAPTER I.

ON THE EPIDERMIS AND ITS APPENDAGES.

EVERY part of a plant, as well as of an animal, with the exception of the stigma or summit of the pistil and the extremities of the roots, is covered by a thin membranaceous investment, termed the epidermis.

Fig. 1.

Pellicle of cabbage, detached by maceration, covering the hairs, *h*, and having openings, *s*, corresponding to the stomata.

The epidermis consists of two parts: 1st, an outward pellicle, (Fig. 1,) without appreciable organization called the cuticle; 2d, one or more strata of flattened tabular cells, which are much larger than the cells of the subjacent tissue, consti-

tuting the true epidermis or skin. These two superposed membranes are intimately united and pierced by a number of apertures, called stomata or pores.

The presence of the cuticle on the exterior surface of the epidermis, may be detected by a simple chemical process. If a transverse section of the epidermis be treated with a dilute solution of iodine, the cells of the epidermis will remain colorless, whilst the cuticle will assume a yellowish or brownish tinge.

Some writers consider the cuticle to be a mere secretion from the epidermic cells on which it is deposited; but the recent investigations of M. Gareau, a distinguished French physiologist, who succeeded in effecting its quantitative analysis, would seem to prove that it is a distinct organ, formed from cellulose of a special matter distinct from that which constitutes the epidermis.

The cuticle is the only part of the epidermis which covers the surface of the stem and leaves of aquatic plants. It is developed in the form of a glaucous bloom or vegetable varnish, which renders the surface of the plant a perfect water shed, preventing it from obtaining an injurious amount of the fluid in which it floats.

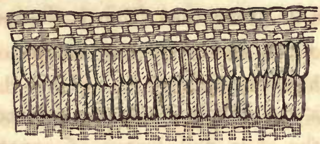
The epidermis (ἐπὶ upon, and δὲρμα skin). In flowering plants, the epidermis may be readily perceived to be a membrane perfectly distinct from the cellular and fibrous tissue which it covers, on account of the magnitude and peculiar arrangement of its cells. The epidermic cells contain ordinarily no traces of chlorophyl, and therefore the epidermis may be readily separated from the parenchymatous tissue, with which it contracts but a feeble adhesion, as a colorless layer.

The epidermis of plants is clearly intended to guard their subjacent vascular and cellular systems from injury, to pro-

tect those systems with their fluid contents against changes in the state of the atmosphere, and to control the evaporation from their cells within proper bounds.

In the Lily and Balsam, which allow of ready evaporation, the epidermis consists of a single layer of cells; but in plants which inhabit dry situations, it is so constructed as to retard evaporation, and either consists of several layers of cells, as in the Oleander, (Fig. 2,) or else is of considerable thickness, as in the Aloe and Cactus. By this provision these plants are enabled to retain their moisture for a greater length of time.

Fig. 2.



Magnified perpendicular section of the leaf of the Oleander, showing the thickness of the epidermis, which is composed of three layers of cells, and the compact vertical cells of the upper stratum of parenchyma.

It must be evident that the exhalation of water from the leaves is to a certain extent necessary, as it is the only means by which the sap can be concentrated and rendered subservient to the nutrition of the plant. Now so long as the roots can absorb as much water as the leaves evaporate, the plant will appear fresh and green, but the foliage droops (as is often seen on a hot summer's day) when the supply at the roots fails, and there is too much evaporation from the leaves.

To remedy this defect, the epidermal surface of the leaves is furnished with self-acting valves or openings, called stomata or pores. These stomata are usually of an oval figure with a slit in the middle, and are so situated as to open directly into the

hollow chambers or air-cavities in the lower stratum of parenchyma. The aqueous contents of the cells of the parenchyma, throughout the whole interior of the leaf, are thus brought into immediate contact with the external air, whilst at the same time the evaporation of their contents is controlled and regulated by these foliar apertures.

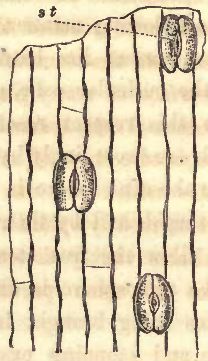
This is done in the following manner. The slit or perforation in the epidermal surface lies between two cells, which, unlike the rest of the cuticular cells, generally contain some chlorophyll, and in this respect resemble the parenchyma beneath. These cells are exceedingly hygrometrical, or affected by moisture. When the atmosphere is damp, these two cells become swollen and turgid, and by their curvature outwardly, open the orifice and allow the free escape of the superfluous water; but when the atmosphere is dry, they straighten and lie parallel, their sides being brought into close contact, thus closing the aperture and stopping evaporation the moment it becomes injurious to the plant. The stomata or pores of plants are therefore analogous to the governor in machinery, and are clearly designed to regulate the operation of the vegetable mechanism, and to promote the healthy passage of fluids through the system.

The structure of the stomata or pores of plants, may be readily perceived on the epidermis of the lily, (Fig. 3,) where they are unusually large. The epidermis must be carefully removed, and having been freed from all its chlorophyll, or green matter, it must be placed between two strips of glass with a drop of water between them so as to give it the necessary degree of transparency. Water ought, for this reason always to be used whenever objects selected from the tissues of vegetables are examined microscopically. The epidermis

thus prepared will exhibit these pores, and the nature and beauty of their mechanism will be seen and appreciated.

The stomata are generally found on the under surface of the leaves, the mechanism being too delicate to act well in direct

Fig. 3.



Epidermis of the lily, showing the stomata *st*, composed of two cells with an opening or slit between them.

sunshine. They are invariably absent from the parts of plants growing beneath the water. The water-lilies (Nuphar and Nymphœa,) and all plants whose leaves float on the water, have the stomata on the upper surface of their leaves. If the leaves of plants grow erect, the stomata are equally distributed on both sides.

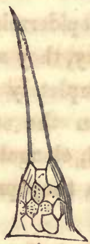
Stomata are more or less abundant on the cuticle of all plants, and as these pores perform the functions of exhalation in proportion to their number on different plants, it is necessary to supply them with water. The plant called Hydrangea quercifolia has on one square inch of its surface 160,000 pores,

and therefore requires a greater supply of water than plants possessed of from 70 to 100 pores on the same superficies.

The rapidity with which plants wither and dry when not watered, is exactly in proportion to the number of their exhaling pores. Thus when a shower of rain occurs after long drought, our readers must have witnessed that many plants revive long before the moisture can have reached their roots. The only absorbents in this case were the stomata on the epidermis.

Occurring on the surface of many plants are certain minute expansions of the epidermal cells termed hairs. These consist either of a single elongated cell, or of several cells, placed end to end. Those hairs which are not connected with any peculiar secretion, are termed lymphatic. Those, on the other hand, which have cellules visibly distended at their base or apex into receptacles of some peculiar fluid, are termed glandular.

Fig. 4.



Magnified view of one of the stinging hairs of the nettle with the gland at its base.

It is from these secreting hairs that the beautiful scent of the sweet brier is derived, and the sting of the common nettle (Fig. 4), is produced by an acrid fluid ejected through its tubular hairs from the glandular receptacles at their base *a*. Nettles have been very properly termed the serpents of the

vegetable world; and not without reason, for there is a remarkable similarity in structure between the poison teeth of the latter and the glandular hairs of the former. In both the apparatus is tubular, and the pressure of the hair or tooth on the poison gland ejects the poison into the system.

The poison of nettles in temperate climates is not of much consequence, but as we approach warmer regions stinging nettles become more numerous and deadly. "Every person is acquainted with the sting of the common nettle, Urtica urens, but no notion can be formed from it of the torture which its allies, Urtica stimulans, Urtica crenulata, produce in the East Indies. A gentle touch is sufficient to make the limb swell up with the most fearful rapidity, and the suffering lasts for weeks; nay, one species, growing in Timor, Urtica urentissima, is called by the natives Daun setan, Devil's Leaf, because the pain lasts for years, and sometimes death itself can only be avoided by the amputation of the injured limb."*

When the hairs of the epidermis are hardened by deposits, as in the rose and blackberry, they are called prickles, (aculei). In their youth, they completely resemble hairs, and are dispersed without order on the stem and leaves, but with age they become thickened, elongated and indurated, as may be seen on the rose, where they present themselves in every stage of development.

Hairs are sometimes attached to seeds for the purpose of scattering them, as in the cotton plant. In Rhus cotinus, or the wig tree, the flower stalks are changed into hairs.

* Dr. Schleiden.

CHAPTER II.

THE DIFFERENT KINDS OF STEM.

THE stem may be regarded as that portion of the axophyte which is situated between its two extremities, and which carries the leaves and the flowers.

The stem exists in all flowering plants, but sometimes, as in Taraxacum dens leonis, the common dandelion, it is hardly developed at all, so that the leaves and even the floral branches appear to spring from the root. These plants were formerly considered to be acaulescent (*a* without, *caulis* a stem); they have, however, a true stem, but it is so contracted in its growth as to be hidden in the earth.

The common idea that all the subterranean parts of plants are roots is quite erroneous. The production of buds and leaves, and the presence of leaf scars, are the distinguishing characteristics of the stem, and the following roots, so called, which exhibit these appearances, are only its subterranean modifications.

The rhizoma, (ῥιζα, a root). This stem pursues an underground course, growing horizontally at a depth in the soil which is sufficient to protect the buds on its surface, from which it sends forth annually herbaceous branches into the air, which die down to the ground at the close of the flowering season. In Polygonatum pubescens, (fig. 5,) the annual decay of the foliage leaves on the rhizoma a broad and conspicuous scar, which is not unlike the impression of a seal, and for this reason the plant is commonly called Solomon's seal.

Fig. 5.

Rhizoma of Solomon's Seal, (Polygonatum pubescens.)

The rhizoma or underground stem grows after the manner of ordinary aerial stems by the development of both lateral and terminal buds. In Polygonatum pubescens the development of the subterranean buds is alone terminal, but in other perennial herbaceous plants the lateral as well as terminal buds of the rhizoma are developed, and the subterranean branches, which are called suckers, send up from the soil aerial stems. These suckers when severed from the parent stem and planted will grow into new plants. This mode of multiplying plants is often resorted to by gardeners, and is called by them, propagating by offshoots.

The bulb. This form of underground stem is much varied. It may be a scaly bulb, as in the lily, or a tunicated bulb, as in the onion. These varieties of bulbs are justly regarded by botanists as subterranean buds or undeveloped stems, being in every respect similar to the ordinary leaf bud, except that as they grow beneath the ground, the scales or imperfect leaves which envelope them are more thick and fleshy. These retain

their rudimentary character as a protective covering to the inner leaves, which grow in a tuft from the earth's surface, the flower stem rising from their centre.

In the tunicated bulb the scales enclose each other in a concentric manner, each scale embracing the entire circumference of the bulb. The outermost scales are thin and dry, the innermost thick and succulent. Tunicated bulbs are restricted to such plants as have sheathing leaves, and which, consequently, embrace at their base the entire circumference of the stem. In the scaly bulb the scales are free from each other and much smaller, being imbricated, or lying one on the other, like the tiles of a house. This bulb belongs only to plants, the leaves of which are sessile, and therefore not connected with the stem by a sheathing base.

Fig. 6.

Fig. 7.

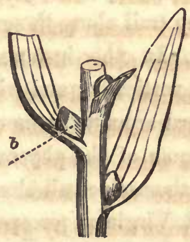


Fig. 6.—Bulb of the garlic with a crop of young bulbs.
Fig. 7.—Axillary bulblets, *b*, of Lilium bulbiferum.

Bulbs being subterranean buds or undeveloped stems, give birth to new buds or bulbs in the axils of their scales, the rudimentary leaf-like nature of which is thus rendered apparent. The young bulbs are called cloves. This mode of increase, is

exemplified in the common garlic, (fig. 6.) In this respect the bulb behaves exactly like a leaf-bud after it has been lengthened into a branch. One or more of these young bulbs or cloves may develope as flowering stems the next season, and thus the same bulb survives and blossoms from year to year.

In some plants, as in Lilium bulbiferum, (fig. 7,) bulbs are produced on the stem in the axils of the leaves, which, when detached from the stem and placed on the ground, will grow into independent plants. These bulbs are called bulblets.

The tuber is a subterranean branch which is arrested in its growth, and becomes remarkably thickened in the place of being elongated. It is seen in the common garden potatoe, the eyes of which are true leaf buds. Hence these tubers when cut into slices, provided the slice contains an eye, will grow and become independent plants.

In the lower forms of their development stems are so weak that they trail along the ground, never rising from the earth's surface. In other instances these weak stems have a tendency to grow vertically; and when this is the case they either twine in a spiral around the more vigorous herbage in their vicinity, or the roots of the phytons take a horizontal development and exhibit themselves all along the side of the axophyte, as in the Ivy and Virginian creeper. By such aerial or adventitious roots such plants attach themselves to the surface of rocks and the bark of trees, and thus elevate themselves to the air and light.

In some plants, such as the pea and vine, the leaves are developed as organs of support. By the non-production of the parenchyma, and the development of the fibro-vascular system, an organ called a tendril is produced, which has a tendency to twine round any body with which it may come in contact.

The tendrils of the vine and pea are well known; let us show the beauty of their mechanism. When the plants are young they are put forth in a straight line, and curved into a sort of hook at their extremity. In this manner they seem as if they were reaching forward for the purpose of catching hold of something on which they can hang for support. If in this state a young twig or branch be borne by the passing breeze within reach of their hook, they immediately catch and coil themselves spirally about it. Now this apparently feeble organ of self-support is in reality a powerful instrument of self-defence, and the storm which can overpower the strength of the forest trees, prostrating them with the earth as it rushes by in all the wildness of its fury, cannot injure these plants. It is rendered harmless in its effects by the elastic yielding of the tendril, which thus secures these weak plants from being broken off from the object to which they have attached themselves, and from sustaining the slightest injury.

In the grasses the stem, which is hollow and fistular, has received the name of culm (*culmus* a straw). This structure also prevails in other plants, and is a beautiful instance of mechanical contrivance to dispose the limited quantity of matter in the stem to the greatest possible advantage, so as to give the greatest strength with the least expenditure of material. By this hollow cylindrical disposition of the matter, an increase of strength is imparted to the vegetable structure equivalent to that of a solid stem of the same diameter. The bones of animals and the feathers of birds are tubes or hollow trunks, combining strength with lightness, and constructed on the same principle.

When the philosopher Galileo was confined in the dungeons of the Inquisition for teaching the *heresy* of the motion of the

earth, he was visited by a Catholic priest, who accused him of Atheism. The persecuted and venerable sage met the accusation by the following beautiful and sublime, though simple and affecting appeal. He took from the floor of the dungeon on which he was lying a wheaten straw, and having explained the mechanical and scientific principles shown in the structure of the stem, told the priest that this was evidence to his mind of the existence of a God. "If," said he, "this wheaten straw, which supports an ear heavier than its whole stock, were made of the same quantity of matter disposed in a solid form, it would make but a poor thin and wiry stem, which would be snapped with the slightest breeze; its tubular form gives it the necessary degree of strength, and preserves it from destruction."

Not only the strength but the duration of stems depends on the degree of their development. A plant is considered to be a herb if its stem invariably dies down to the ground each year. Some herbs are only annuals arriving at their full development and the term of their existence in one year, the act of reproduction exhausting their vital energies. In biennial herbs the whole of the nutriment assimilated by the vegetative organs the first year is consumed by the act of reproduction in the second, and the plant necessarily perishes. In herbaceous perennials the upper part of the plant only dies, life retreats into the rhizoma, and with the return of light and heat to the earth in Spring, the plant again makes its appearance above the ground, and developes into its wonted figure and hues.

The same species may become an annual, biennial, or even a perennial, according to the treatment which it receives, and the circumstances in which it is placed. If an annual plant be deprived of its flowers and preserved from the inclemency of

winter, it will become a biennial. On the other hand, tropical perennial plants, when transported into temperate climates become annuals. For example; The beautiful climbing vine so much cultivated called (Cobæa scandens,) and which endures but for a year in these latitudes, is a perennial in Chili and Peru its native country; so also the castor oil plant, (Ricinus communis), which in Africa forms an elevated tree, is an annual with us.

In the more highly developed plants, such as shrubs and forest trees, the act of flowering and fruiting consumes only the nutriment enclosed in the peduncle and its immediate supports, but the rest of the plant is not injured. Yonder leafless tree, whose branches wave in the winter's wind, loaded with snow, is still fraught with life. All along its central axis, in its branches, and innumerable branchlets life exists, dormant beneath the scales of its numerous buds. The last vegetative process of plants with ligneous and persistent stems, in autumn, is, in fact, the formation of the bud, wherein life lies dormant, yet protected from the severest cold of winter until spring awakens it to a new existence. The following year these buds or phytons (*φυτὸν*, a plant,) as they have been correctly named, develope on the stem or axophyte, and from them ligneous matter descends, which gives an additional enlargement and strength to the vegetable axis. In forest trees, therefore, the stem acquires its greatest development. A forest tree, philosophically considered, is not an individual plant, as is commonly supposed, but a community of individual plants growing together about a common vegetable axis. These phytons have a downward as well as an upward development, and the stem or axophyte is formed by the commingling of the ligneous or fibrous matter which descends from them, and which spreads

in the earth as in the atmosphere in a form beautifully appropriate to the altered condition of the medium.

CHAPTER III.

ON THE ROOT OR SUBTERRANEAN APPENDAGES OF THE AXOPHYTE.

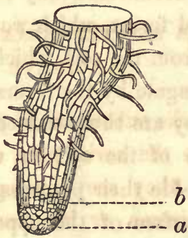
THE rhizoma or the subterranean part of the vegetable axis, has appendages like the aerial part, organically adapted to the medium in which they are developed. These appendages, emitted by the rhizome or its ramifications, are ordinarily under the form of fibres more or less slender and delicate, commonly cylindrical, simple or branched, called radicle fibres. It is the assemblage of these fibres which constitute the true root, that is to say, the organ whose function is to draw from the soil a part of the elements necessary to the life and development of the plant.

Each of these fibres is terminated by a blunt and rounded extremity, which has received the name of spongiole. For a long time this was considered to be the only part of the root which absorbed liquids. But it is now ascertained that absorption takes place throughout the whole extent of the radicle fibres, the centre of which is occupied by bundles of vessels.

The spongioles or spongelets ought not to be reckoned special organs. Fig. 8 is the extremity of the young root of the sugar maple, (Acer saccharinum,) highly magnified. Now the cellular extremity of the root or the spongiole, *a*, does not consist of the cells most recently formed, which are in reality an

older mass of cells, pushed forward by the growth of the cells at *b*, immediately behind them. The cells of the point consist of older, denser tissues, as inspection plainly shows; and as these decay and fall away, they are replaced by the layer beneath. The point of all root fibres is capped in this way.

Fig. 8.



It would appear from this that absorption does not take place to any considerable extent at the apex of the root, but principally through the more recently formed tissues behind it, and especially by those capillary cells or root hairs with which the surface of all young and growing roots is usually covered. These root hairs are in general more abundant and more developed on plants growing in loose, dry sand. Such plants, in order to obtain as much moisture as possible from the unfavorable element in which they are placed, shoot forth from every fibre an incalculable number of them.

Roots produce radicle fibres and root-hairs instead of leaves, and these organs like leaves are deciduous towards autumn, being annually renewed every spring. Hence the best time for transplanting is in winter, when the fibres are dead or torpid, or in early spring before they are renewed. Transplanting after the season of growth has fully commenced is always attended with more or less injury to the plant.

In growing, the roots of plants therefore do not elongate through their entire length, but increase by the addition of matter to their advancing points, very much like an icicle, except that the new matter is added from within and not from without. Growing in a medium of such unequal resistance as the soil, they elongated through their entire length they would, when they encountered any obstacle, be thrown into knotted and contorted forms, which would prevent their acting as conduits of food from the soil, which is their peculiar office. But as they only elongate by the formation of fresh tissue at their extremities, they are thus enabled to accommodate themselves to the nature of the soil in which they grow; and, should any thing impede their progress, they sustain no injury, but following the surface of the opposing matter, they grow and extend themselves until they again enter a softer and more favorable medium. In this manner they penetrate the soil, as it were, in search of food, insinuating themselves into the minutest crevices of rocks, and extending themselves from place to place, as the nutriment in their own immediate neighborhood is consumed.

Now all newly formed vegetable is extremely hygrometrical, and hence absorption takes place throughout the whole extent of the newly formed tissue.

The law which regulates this absorption has been recently discovered by M. Dutrochet, a distinguished French physiologist. It is this: if two fluids of unequal densities be separated by an animal or vegetable membrane, the denser fluid will draw the lighter through the membrane with a force proportional to the difference of density of the two fluids. A simple experiment will illustrate this. (Fig. 9).

Take a short tube, and cover one end with a piece of blad-

der; partly fill the tube with a strong solution of sugar, and immerse it in a vessel containing water. In an hour, or more, the denser fluid will be found to have attracted the water through the membrane and to have risen considerably in the tube. This property is called Endosmosis, (*ἔνδον*, inwards, *μάω*, I seek.)

Fig. 9.

Now the cells of the roots and the entire system of the plant, owing to the evaporation of water from the leaves, always contain a fluid dense and concentrated. The water in the earth is therefore attracted into the plant by means of the denser fluid contained in the cells of the root,—or in other words, it enters the plant by endosmosis.

This simple endosmotic law pervades all vitally active and newly formed vegetable tissues, and seems to be the only cause of all the remarkable movements of roots. For example, it is well known that roots will turn aside from a barren for a fertile soil, so that to stop their growth in any given direction,

it is only necessary to interpose a trench of gravel or sand between them and the premises they are forbidden. How is this to be accounted for? Are we to suppose, as some have done, a sort of prescience on the part of the vegetable? On the contrary, is it not all clearly explicable on the principle of endosmosis? There is always, in the forming and vitally active cells at the extremities of the roots, a thicker fluid than the fluid in earth; the fluid in the earth is attracted by endosmosis through the cell walls into the system of the plant, and becoming assimilated, the newly formed cells of the roots necessarily take the direction of the most fertile and favorable soil.

Roots developing in the soil have a natural tendency to an avoidance of the light, whilst the stem and leaves seem to seek for the same. Hence hyacinth bulbs will grow much better in water-glasses which are of a dark color, than in white uncolored ones. So also when Dutrochet caused a misseltoe seed to germinate on the inside of a window pane, it sent its roots inwards towards the apartment; when on the outside of the pane it did the same. Hence when seed is sown by nature or the hand of art, however the seed may fall, yet in germination the radicle so bends itself as to sink perpendicularly into the soil, whilst the stem rises perpendicularly from it.

The force with which the radicle or root descends is very considerable, and many attempts have been made to change its obstinate tendency to burrow in the ground, but without effect. We know not yet the cause of this invincible tendency of the radicle *towards the earth's centre.* It has been thought that the humidity which exists in greater abundance in the soil exercises a sort of attraction on the radicle, but Duhamel has shown that it is not so. He caused seeds to germinate between

two sponges, saturated with water, brought near each other, and suspended in the air by means of a double thread. When germination was sufficiently advanced, the radicles instead of bearing to the right and left towards the water in the sponges, glided between them, so that they ultimately hung below them into the atmosphere. It is not then the humidity in the soil which causes the radicles to penetrate its surface. It would rather seem that this tendency ought to be attributed to a particular force, which developes a sort of polarity at the period of germination, which produces an opposition of growth in the two extremities of the vegetable embryo, causing the plumule to rise towards the zenith, and the radicle to move in the direction of the earth's centre.

The radicle fibres generally spring from the subterranean portions of the axophyte, but the aerial portions of that organ are equally capable of emitting them. When this is the case they are designated under the name of aerial or adventitious roots. Some woody vines, as the Bignonia or Trumpet-creeper, the Rhus toxicodendron or Poison ivy, and the Hedera helix or European ivy, climb by aerial rootlets, in which way they reach the summits of the tallest trees, and loftiest buildings, giving beauty even to the mouldering ruin. Such plants, however, derive their nutriment from their ordinary roots embedded in the soil, their copious aerial rootlets merely serving them for mechanical support. The tenacity with which these aerial rootlets adhere to trees, rocks, and even to the hardest flint, is truly astonishing; and the height to which the plants themselves will ascend, seems to cease only because they can find nothing higher on which they can support themselves. In warm climates these twining plants (*lianas*) take a much higher degree of development; their stems are ligneous,

persistent, and sometimes very thick, whilst with us they are very slender and herbaceous and perish annually. Heat and humidity are powerful agents in promoting vegetation, and hence its superior activity in the tropics.

The roots emitted by the aerial portion of the axophyte sometimes remain free and floating in the atmosphere, and sometimes they descend as far as the soil, which they penetrate in order to draw from it additional nourishment. These peculiarities are observable in many of the vegetables of the warm and sunny South. A great many palms, figs, and orchideous plants develope these roots.

When the roots continue aerial, the plants are termed epiphytes (ἐπὶ upon, and φυτὸν plant). They are so called because they grow to other plants as mere points of attachment, dropping their roots into the atmosphere from which they derive all their food, and which always continue aerial and greenish, and to distinguish them from parasites, which obtain their nutriment from the plant on which they are found. These plants abound in the tropical forests of South America, which they enrich and beautify by their gorgeous and fragrant flowers. That the trees on which they grow are mere points of attachment, and not sources of food, is evident from the fact that they may be attached to any substance whatever, as for instance to the rafters of the stove or hot house, where they will grow with an equal amount of vigor and luxuriance.

The roots of the epiphytes or air-plants as naturally avoid the ground and darkness as the roots of other plants seek for the same; they require air and light, and may be seen searching for it in the warm, moist atmosphere of the conservatories, through the crevices of the baskets filled with chips and charcoal in which they are generally kept. In other instances,

these aerial roots emitted from the stem into the open air, descend to the ground, and establish themselves in the soil. Many plants of tropical climates present this phenomena. Amongst which we may mention the Ficus religiosa, or

Fig. 10.

An Epiphytic orchid (Maxillaria) of warm climates.

Banyan tree of British India. This tree drops from its horizontal branches, roots into the air, which, swinging in the breeze like pendant cords, do finally reach the soil, into which they penetrate, when they become metamorphosed or changed into stems, and increasing in diameter, give nutriment and a natural support or prop to the heavy branches from which they originally descended, so that those branches can extend laterally still farther from their parent trunk. By numerous growths of this kind, one tree ultimately becomes the centre of a family forest, their united branches and foliage spreading over a considerable extent of ground.

The Pandanus or Screw pine may be cited as another instance. In this case, when the tree is much exposed to the powerful winds of the tropics, strong roots are emitted from the lower part of the main trunk, which, striking into the soil,

act as props to the stem, giving the tree the appearance of having been raised from the ground. If, however, the tree is under shelter, or cultivated in a stove or hot-house, those thick, strong roots or props, provided by nature, do not develop, but are still seen as protuberances on the surface of the stem. The same phenomena is perceptible on a small scale in the stem of the Zea mays, or Indian corn, the lower joints of which give forth aërial rootlets, which reach or do not reach the soil, according to the amount of support required by the plant.

In general it may be remarked, that these adventitious roots are developed from those parts of the stem where the nutritive sap encounters some obstacle to its free circulation, and in particular at the nodes or accidental nodosities which exist on the stem or its branches.

We are able, whenever we please, to produce these adventitious roots on the young branches of most ligneous vegetables. It is only necessary to surround the young branch with humid earth contained in any kind of pot or vase. At the end of a definite period, varying according to the species, the roots will develop themselves, and the young branch can be separated and will form another plant. This is a mode of multiplication very useful in horticulture.

We see the same results produced continually in nature under similar circumstances. Most creeping stems produce roots at every leaf node, that is to say, when there are the suitable conditions, moisture, a certain amount of shade, and immediate contact with the earth; and the branches of such stems as are vertical, if bent to the ground and covered with earth, almost always take root. This is sometimes done by gardeners, who bury the limbs of shrubs by bending down the

body of the tree, after which each limb, being severed from the parent, forms a new tree.

Separate pieces of young stems containing a bud, and called by gardeners cuttings, will also take root if due care be taken with them. For a tree is not an individual, as is commonly supposed, but a collection of individuals, an elongation of individual buds, which, in their development into branches, live on their parent stem, into which they send down roots just as that parent stem itself sends its roots into the soil. For this reason the bud of one plant may be transferred to the stem of a similar or nearly related species, to which, if it be carefully fitted, it will soon become rooted and develope into a branch, being sustained by the stem, into which it has been engrafted equally with the natural branches of the tree.

The observations of Mohl and Unger, both eminent physiologists, have proved that adventitious or aerial roots are all formed in a very similar manner. They show themselves at first under the form of a little conical excrescence or tubercle, the base of which rests on the wood. As they increase, they turn aside the cells of the tuber and cortical parenchyma which they traverse, and finally form a slight prominence under the epidermis. A little later, the epidermis is torn in a direction parallel to the axis or stem, and the root shows itself at the exterior and directs itself towards the soil.

The roots of plants generally bury themselves in the soil, but some plants are parasites (παρα beside, σίτος food), or derive their nutriment from the plants on which they grow and into which they fix their roots, and cannot therefore be cultivated on the ground. Some parasites grow on the roots of trees, as the Epiphegus Virginiana, or beech drops, which is found beneath the shade of beech trees, and on the roots of

which it is parasitic; others attach themselves to the stem and branches of trees, as the cuscuta or dodder and Viscum flavescens or mistletoe.

The Indian pipe (Monotropa uniflora) is one of the most remarkable of our native parasites. This plant may be found occasionally in the deep, rich woods of North America, during the summer months. It is a singularly pallid and fungous-looking plant, to which order it seems to approximate not only in appearance, but also in the exercise of its functions. It is fleshy, scentless, and snow-white throughout, and rises to a height of from four to eight inches above the ground, bearing at its summit a solitary terminal flower, which is at first drooping, and in this state the plant looks not unlike a pipe in appearance, but afterwards becomes erect. The whole of the plant turns black in drying.

The roots of many species of plants are not fixed to any substance whatever, the plant possessing a sort of locomotive power. This is the case with several kinds of aquatic plants, as the Lemna, or duckmeat, a little frond-like plant, which covers the surface of stagnant pools with its scum-like vegetation, and drops its little filiform roots into the water, on the surface of which it floats. So also the Fucus natans, a species of marine algæ, is found in the Gulf of Florida and other parts of the ocean, floating many hundreds of miles away from land. This plant has no distinct root, and is of course found only within certain latitudes.

Functions of roots.—The principal function of roots, consists in drawing from the earth, or from any other medium in the midst of which they are plunged, those substances which serve for the nutrition of the plant. Their organization and vital phenomena prove this.

M. Macaire has proved that plants possess the power of excreting by their roots such injurious matters as they may occasionally necessarily meet with in the soil, and absorb from it in the progress of their development under ground. This gentleman took a fibrous-rooted plant, and having separated its fibres into two sets, he placed one set in a glass containing distilled water, and the other in a solution of acetate of lead. After a few days he found that the fibres dipping into the solution of acetate of lead, had taken up that poison into the plant, but that the same poison had been excreted or thrown out by the other set of fibres into the glass containing distilled water. For on applying sulphuretted hydrogen, the test for the acetate, he found the distilled water was impregnated with it.

In this experiment we see that the poison was forced into the circulatory system of the plant, which induced a self-preservative effort on its part analogous to that made in the higher forms of life. All the experiments made on plants with narcotics and other poisons prove that they possess a principle of life analogous to that of animals.

The roots of plants when developed in the soil, are also clearly designed to fix them in an upright position, so as to prevent them from being overturned by animals, by the force of the winds, or by any other cause. Hence it is that the roots of a tree are always most numerous and strong to windward, or in the direction of the prevailing winds. When the tree is sheltered on every side, there is little lateral extension of its roots, and they naturally develope downwards into the earth. So also the roots of trees growing on the sides of roads or the banks of rivers, will curve into the embankment, and thus prevent the tree from being undermined or washed away.

The roots of rock plants adhere to their surface and crevices with the most astonishing tenacity; as for example, the beautiful wild columbine, (Aquilegia Canadensis,) one of the early spring flowers of the northern States.

The roots of plants, particularly, the fibrous and matted roots of the sedge and grass tribe, bind together the loose soil on the sea-shore, and prevent it from drifting inland. On many coasts, the inward drift of the sand by the strong sea breezes which prevail, produces hills of sand called dunes. The safety of these shores is greatly promoted by a species of grass called the Arundo arenaria, whose thick and matted roots bind together the loose sand and prevent its desolating effects.

That disintegration and destruction of rocks mechanically and chemically, which is continually going forward in nature, is also prevented from being carried forward to an injurious extent by the fibrous roots of grasses and other plants.

It is a fact well known to practical geologists, that when rocks rise above the surface of the earth in cliffs and ridges, they become exposed to the mechanical and chemical action of the atmosphere, and their surface gradually shivers off, crumbles down, and wears away. Hence loose matter collects at the bottom of the escarpment, forming in the course of ages, a slope of disintegrated material, called by geologists a talus. The process of disintegration continues until the talus of fallen fragments has accumulated to the very summit of the escarpment, so as to hide it altogether. Now so long as the face of the escarpment is exposed, and the fall of the detached fragments continues, vegetation will not seize on the slope; but when the disintegrated material has acquired that degree of sloping, which is called by geologists, the angle of repose, or has accumulated to the very summit of the escarpment, no

more fragments will roll down, and vegetation will cover the slope. Vegetation appears on no soil but what is in a state of rest, and when it is once established in any place, it is not only a sure indication that the soil is at rest, but a means of keeping it so. It is by operations of this kind, not performed in a day, but in ages, that rugged peaks and abrupt precipices are gradually transformed into rounded summits, gentle slopes, and habitable surfaces. On precisely the same principle, the sloping sides of railways are secured from disintegration and destruction, by being sown with grass seeds or covered with grass sods.

The lower orders of the Cryptogamia, or flowerless plants, such as lichens and mosses, appear to derive their nutriment mainly from the atmosphere. Mosses appear to take in their nutriment from the air by their whole expanded surface, although doubtless the delicate root hairs below that surface perform their part in absorption. Hence some species are only found growing on the bark of trees, others on rocks and boulders, whilst numerous genera cover the surface of the ground. The roots of lichens, when they have any, are mere holdfasts, the plant being developed wholly from the atmosphere. Some species, however, would seem to attach themselves to stones of a calcareous, whilst others form a beautiful plaiting on the surface of whins, sandstones and granites. These atmospheric cryptogamia, are the first plants which clothe the surface of barren rocks, and by their decay form a humus or foothold for a more highly organized vegetation.

CHAPTER IV.

ON THE ORGANIZATION OF THE STEM.

When we examine anatomically the stems of phanerogamous plants, we find them to be remarkably similar in their internal structure. The stems of forest trees, ligneous and persistent for centuries, differ only from the stems of the herbaceous and humble plants which grow beneath their shade, in the degree of their development; they are constructed on precisely the same plan, and in all the varieties of their growth, for the most part, are reducible to either one or the other of the two following forms of vegetable organization.

The exogenous (ἔξω, outward, and γεννάειν, to produce,) or outside-growing stem, so called, because this kind of stem increases in diameter by successive annual additions of bundles of vascular and fibrous tissue to its outside. Such a stem exhibits on the cross-section a number of concentric rings of wood, which mark the successive annual growths of the tree, surrounding a central column of pith, the whole enclosed by a hollow cylinder of bark. The forest trees of the northern United States, and the major part of our herbaceous plants, are all constructed on this plan; and the cross-sections of an oak branch, or of any other tree, will show the rings, and the nature of an exogenous stem.

The endogenous (ἔνδον, within,) or inside-growing stem, so called, because it increases in diameter by successive additions of fibro-vascular and cellular matter to its inside. The growth of these plants is carried on by means of the thick cluster of

leaves with which they are terminated superiorly, and from them the new vegetable matter descends along the centre of the stem, and pushes outward the parts first formed.

The oldest and hardest part of the stem of an endogen is that nearest the circumference; for the more the external parts are pressed by the descent internally of new vegetable matter, the denser must they necessarily become. It is owing to this external hardness that many endogenous plants have no lateral buds or branches, because they are unable to penetrate the hard casing of the stem.

On the cross-section, the stem of an endogen is not distinguishable into bark, wood, and pith, neither does it present any appearance of concentric rings; for the stem of an endogen is composed of separate bundles of vascular or woody tissue irregularly imbedded in a mass of cellular tissue, which bundles are distinctly traceable down into the stem from the base of the leaves at its summit, and then curving outwards they generally terminate in the bark. Hence on the cross-section the cut ends of these bundles are visible in the form of dots, interspersed through the uniform cellular tissue, without any apparent order, although more commonly crowded towards the circumference. Hence, also, we see the reason why the bark of an endogen is inseparable from the rest of the stem without a laceration of its fibres.

The plants whose structure is endogenous in the northern United States are few, and, with the exception of the green brier, entirely herbaceous. The grasses, the iris, the Indian corn, are humble representatives of endogenous plants, which attain their full development and display their noble arborescent forms only under the influence of a tropical sun. The palms, screw pines, plantains, and bananas of the tropics, are all endo-

genous, and present a striking contrast to the exogens of temperate latitudes. A tall, cylindrical and unbranched stem rises to the height of from 100 to 150 feet, crowned at the summit with a magnificent cluster of leaves, many feet in length, bending elegantly downwards, and presenting altogether one of the most graceful and beautiful objects that can adorn a landscape.

The Exogenous Stem.—Since the exogenous class of plants is by far the largest in every part of the world, and embraces all the trees and shrubs with which we are familiar in northern climates, the structure of this kind of stem demands a more detailed and particular investigation. Every exogenous stem presents, on the cross-section, an arrangement of matter into three parts, called, respectively, the bark, the wood, and the pith. To obtain, however, a clear idea of the origin of the exogenous stems, it is necessary to follow the course of the development of the stem from the embryo state.

The first year's growth.—If we place a seed in the ground at the temperature of 32° Fahr., it will remain inactive until it finally decays; but, if the earth be moist and above the temperature of 32°, and the seed be effectually screened from the action of the light, its integuments will gradually imbibe moisture, soften, and swell, oxygen will be absorbed, carbonic acid expelled, and the vital action of the embryo will commence. It now elongates downwards into the earth by its radicle, and upwards into the air by its plumule, or young stem, lifting the cotyledons above the earth's surface. The cotyledons thus elevated acquire a green color, by the deposition of carbon absorbed from the atmosphere under the influence of solar light, and ultimately assume the form of two opposite leaves. The process of germination is now completed, and the root, stem and leaves being formed, we have a simple

plant perfect in all its parts and dependent for its future growth and sustenance on its leaves and roots.

Let us now examine the successive modifications of the internal structure, from the commencement of germination to the growth of the first pair of leaves and the completion of this the first stage of vegetation. At first the embryo consists wholly of cellular tissue; as soon, however, as it begins to grow, even while the cotyledons only are developing, some of the cells begin to elongate into tubes longitudinally, assuming the form of vascular and woody fibre. These nascent wood-cells extend upwards into the cotyledons, and downwards into the radicle, and are finally seen in a cylindrical form in the centre of the stem. This longitudinal elongation of the cells does not take place at random, but *certain determinate* cells only thus change their character, whilst the others wholly retain or depart but slightly from their primitive form. A horizontal section of the plumule at this stage of development will show this.

The sap elaborated in the first pair of leaves contributes to the upward growth of the plumule or young stem, and to the development of the second pair of leaves; the new wood-cells extend through them to form their frame-work, making the woody stratum in the second internode as it lengthens, and contributing at the same time to the increase of the stem beneath them; and the same process is repeated throughout the whole growth of the season with every fresh development of leaves.

The woody fibre having rapidly increased, ascending and descending the stem with the growth of every new set of leaves, the medullary rays ultimately become so much compressed, that they assume the form of fine lines radiating from the centre to the circumference of the stem.

In exogenous stems of a single year's growth we therefore observe, a central cellular pith, a zone of woody fibre and vascular tissue, an exterior coating of bark, and medullary rays passing from the pith to the bark. This is the complete structure of exogenous herbaceous stems which die down to the ground annually.

In exogenous stems which are not annual, at the close of the growing season the stem ceases to elongate, the old leaves gradually fall off, the new leaves, instead of expanding after their formation, retain their rudimentary condition, harden and fold over one another, and a bud is produced, the winter's residence of the shoot.

The second year's growth.—The next year, with the return of light and heat to the earth in Spring, vegetation re-commences. The resinous exudation on the buds is melted by the heat of the sun; the scales fall off, the leaves expand, and are separated by the growth of the internodes, the buds terminal and lateral are in this manner elongated into shoots, and are now to the parent shoot what the young leaves were to it the first year; that is, they perform precisely the same functions, and contribute by their downward growth, and their deposit of woody and fibrous matter, to the increased diameter of the parent shoot.

With the development of the buds into shoots and leaves, the sap is set into circulation through the system of the plant, and the bark and wood which, at the close of the growing season, or in autumn, firmly adhered together, are now easily separable from each other, by the formation between them of a stratum of mucilaginous, organizable matter, termed cambium. This cambium is nothing more than the ordinary sap, the water of which having been evaporated in the leaves, is

necessarily thickened and well charged with assimilated matters, and is interposed between the wood and bark where growth is going on. "It is quite wrong," says Dr. Gray, "to suppose that there is any real interruption between the wood and the bark at this or any other period of time, leaving a space filled with extravasated sap. A series of delicate slices will at any time show that the bark and wood are always organically connected with each other, by a very delicate tissue of vitally active partly grown cells." The cambium thus deposited between the wood and bark becomes organized into cells, and forms a new addition of matter to each. Hence, the forming stratum is termed the cambium layer, the inner portion of which forms wood, and the outer, bark. It is when this process of growth is most rapidly going on, in spring or early summer, and the whole cambium layer is gorged with the flow of sap, that the bark and wood are so easily separated. But the separation is effected by the rending of a delicate new tissue.

At the end of the second year, the cambium layer of new wood and bark hardens, the second annual layer or ring of wood and bark is formed, and the bark and wood again adhere firmly together. The new shoots are prepared for winter in precisely the same manner as the first year's shoot was prepared, and are elongated cones as was the first.

In like manner will the plant continue to grow throughout the third, fourth, and succeeding years, each annual growth being only a repetition of the same phenomena.

After a certain number of years the tree arrives at the full perfection of its growth, the outer layers of bark now become fissured and rent, and are exfoliated or thrown off from the stem, and the alburnum or sapwood becomes changed into

duramen or heartwood, which ultimately decays and falls away leaving the interior of the stem rotten and hollow. These changes in the external and internal appearance of the stem are the necessary results of the following peculiarities of its growth.

We have seen that one layer of bark and one layer of wood is annually deposited from the viscid mucilaginous matter called cambium, which makes its appearance between the bark and the wood in spring. It follows, that the number of annual layers or rings of bark ought to correspond to the number of annual layers or rings of wood. Sometimes in the bark of young shoots of two or three years growth these annual deposits may be traced, but in general the successive layers of bark are so amalgamated by the *internal* growth and consequent pressure of new strata of bark, that it is impossible to distinguish them. To the same cause is to be attributed the fissuring and exfoliation of the outer layers of bark. The diameter of the wood is a constantly increasing quantity, because the growth of the wood is exogenous, each new layer of wood being deposited on the outside of the last annual layer, and therefore each ring of the wood remains unaltered in its dimensions and position until it finally decays; on the other hand, an increase in the diameter of the bark is constantly prevented by the endogenous growth of the bark, each new layer of bark being deposited on the inside of the last annual layer; and as new layers of bark are deposited internally, the previous annual layers are subjected to gradual but incessant distention, and finally unable to bear the stretch, are fissured and torn into clefts and rents, causing that cracked and rugged appearance of the bark of trees with which all are familiar. Hence it is that on the cross-section the bark bears but a

small proportion in thickness to the wood; the amount of bark which remains deposited about the wood is exactly proportionate to the stretch or tension to which it will submit, varying greatly in different species. In the old trunks of some pines and firs, it sometimes attains the thickness of from eight to twelve inches, whilst in the Platanus occidentalis, or common plane-tree, after the eighth or tenth year, all the epiphlœum or old and outer layers of bark fall away entirely in the form of brittle plates.

The duramen or heartwood.—The sap chiefly circulates in the inner bark and alburnum where growth is going on, the new and fresh tissues being most active in its transmission. The walls of the cells soon begin to thicken by the internal deposition of mineral matter or sclerogen imbibed through the pores of the roots with the sap, and what was once sapwood is every year, by the development of new rings of wood removed farther and farther from the region of growth; after a few years, therefore, it ceases to take part in the vital operations of the plant, its color changes, and it becomes what is called duramen or heartwood

As the duramen or heartwood does not assist in maintaining the functions of the tree, it may decay without injury to the vitality of the plant. Hence it is that we sometimes see old trees covered with the most luxuriant foliage, although their inside is totally gone.

Having taken a cursory view of the development of an exogenous stem, from the period when it first emerges from its cotyledons or seed leaves, to that term of its existence when it begins to show signs of decay in its interior, we shall now attempt a more careful analysis of the different layers of bark,

wood, and pith which the stem exhibits on its transverse section.

Fig. 11.

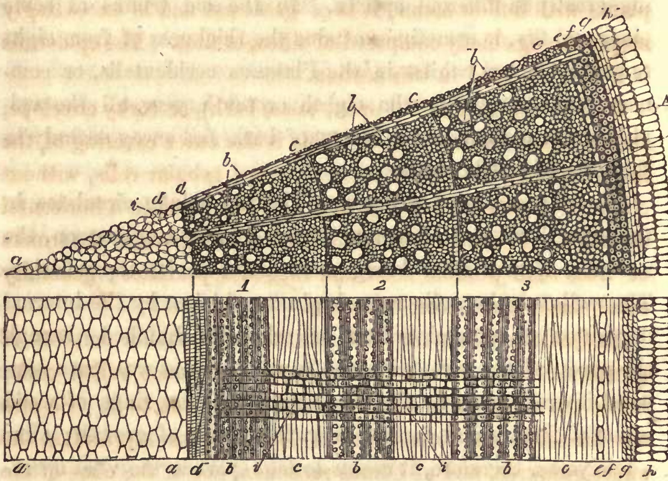


Fig. 11 shows a transverse section A, and vertical section B, of an exogenous or dicotyledonous stem of three years' growth. "In both sections, *a* represents the cellular tissue of the pith, *b b*, the dotted ducts, and *c c*, the woody fibre of the successive annual layers; *d d*, the spiral vessels of the medullary sheath; *e e*, cambium layer; *f f*, liber; *g g*, cellular envelope; *h h*, corky layer; *i i*, medullary rays. In the vertical section the medullary ray is shown in only part of its length; since the continuity of the medullary rays from the pith to the bark, owing to the slight flexure which always occurs in them, is rarely or never shown by such a section."*

The Bark.—From this section, it is evident that the bark, anatomically considered, may be subdivided into four parts.

1. *The epidermis* or general outer integument. The nature of this investment has been already examined pp. (18–24). It only remains at present to add, that in forest trees and larger

* See Carpenter's "Principles of Physiology, General and Comparative," 3d edition, 1851.

shrubs, the bodies of which are of a firm and vigorous texture, it is a part of little importance, excepting in the young and tender state of the plant; but in reeds, grasses, and other plants with hollow stems, it is of great use and is exceedingly strong, being chiefly composed of silica, or flint. The epidermis is not represented in this section.

2. *The epiphlœum* (ἐπί upon, φλοιος bark), or corky envelope, shown in the section at *h h*. This is the outer covering of the bark, and consists of cubical or flattened tubular cells, without chlorophyl, placed close together and elongated in a horizontal direction. It is this part of the bark which gives to the trunks of trees their peculiar color and rugged appearance; generally some shade of ash-color or brown.

In Quercus suber, the cork oak, the epiphlœum consists of numerous strata of cells, forming the substance called cork; hence the name corky envelope, which is given to it. So also the branches and branchlets of Liquidambar styraciflua, the sweet gum-tree, and of Ulmus racemosa, one of the elms of the northern United States, are winged with corky ridges, the result of an unusual development of the epiphlœum of the bark. In the currant and birch, the epiphlœum is composed of only a few layers of cells, and may be seen peeling off in thin circular pieces from the trunks of these trees. When the epiphlœum is very thick, it is simply fissured or rent, in which state it remains attached to the outside of the stem, forming an excellent protective envelope to the inner and vitally active layers of bark.

3. *The mesophlœum* or cellular envelope, represented at *g. g.* This lies immediately on the outside of the liber. Its cells contain chlorophyl, and are developed vertically. It is, therefore, that part of the bark which is colored green, and which

gives to young shoots their green hues, as it shines through the transparent membrane, the cuticle. In the shoots of young trees, in the spring, it may be readily perceived. The bark of a young stem the first year always assumes this color, from the production of chlorophyl in its superficial cells, owing to their direct exposure to the solar light.

The mesophlœum or green layer of bark, does not grow at all after the first or second year. It is excluded from the light by the gradually exterior deposition of layers of epiphlœum, and finally perishes never to be renewed again.

4. *The endophlœum* or inner bark, called also the liber, *f f.* This constitutes the fibrous portion of the bark, the corky and cellular envelopes being composed exclusively of cellular tissue. It is in the fibrous portion of the bark that the sap vessels are contained, which convey the sap from the roots to the highest extremities of the plant; hence the endophlœum continues to grow throughout the life of the plant, being formed in conjunction with the alburnum or sapwood directly from the cambium layer.

The endophlœum or inner bark possesses considerable strength and many useful properties. The inner layers of Tilia Europœa, or the lime tree, when separated by maceration in water, form the common bass or matting used by gardeners, and the woody fibre which is used for the manufacture of cordage in all exogenous plants, as in hemp, flax, &c., belongs to the endophlœum or inner bark, and not to the wood.

The cambium layer, e e. This layer has been already described, pp. (50–1). In herbaceous plants it is not able to organize itself, because the stem dies down to the ground the first year. In every other respect the herbaceous stem offers the same structure as the ligneous, being composed equally of

bark, of wood, and of pith, but the cambium layer is not there, and therefore it wants the elements necessary to the formation of a new layer of bark and a new layer of wood.

In the second year, the gelatinous tissue of the cambium is subjected to the following changes. We have seen that it occupies an intermediate position between the bark and the wood. This zone of cambium cells produces at every point beds of the same nature as those with which it is in immediate contact, and is developed into ligneous and cortical fibre, preserving its cellular organization only in those portions which correspond to the medullary rays. The inner portion of the cambium layer forms the wood, the outer portion the bark, and the new cells of both layers thus mould themselves entirely on the older cells throughout all their points of contact.

That the bark increases in diameter by the deposition of new layers of bark internally, was first proved by Duhamel, a celebrated French physiologist, by the following simple experiment. He passed a metallic thread between the liber and wood of a young tree, and cutting down the tree several years after, he found, on examination of the cross-section, that rings of bark coinciding in number with the years elapsed since he placed the wire next the wood, had grown between the wire and the wood, so that the wire was separated from the wood by a considerable thickness of bark. No experiment can be imagined more decisive than this, of the growth of the bark in diameter by internal deposition of matter.

The wood.—This consists of two parts, the alburnum or sap wood, and the duramen or heart wood. *The alburnum or sap wood*, so called because the sap circulates through it, and also in allusion to its white or pale color. The alburnum is the zone or ring of wood last formed. It consists of elongated

tubes of woody fibre, *c c*, intermixed with bothrenchyma or porous vessels, *b b*. On holding up a thin traverse section of an oak or ash stem to the light, the porous vessels will be seen in the form of large round openings in the tissue, which, situated near the margin of each woody circle or zone, renders apparent the annual growths of the stem. In the maple, plane, and lime tree, these openings are smaller and more diffused, and hence there is an indistinctness in the line of demarcation between the successive zones.

This new layer of wood gradually loses its softness as the season advances, and towards the middle of winter is condensed into a solid ring of wood. In this country, and in Europe generally, there is a periodical check to vegetation during the colder part of the year, which occasions the annual layers found in the stem of exogenous trees. These annual rings, which are distinctly seen in most trees of temperate climates when a section of their stem is examined, serve as natural marks by which to distinguish their age. Thus, suppose an elm, or any other tree to be felled, and the section near the ground to have thirty-five circles, or rings of wood, it may be inferred that the tree is thirty-five years of age.

This computation, however, can only be made in trees which have these rings distinctly marked, and even then there are sources of deception of which it is proper that the student should be informed. For example, a warm spring followed by weather cold enough to check vegetation, will leave a ring in the stem, and the subsequent growth of the stem, with the return of warm weather will give on the cross-section the appearance of two rings of wood, or of two years growth, to the growth of one year; on the other hand a warm winter, by keeping the tree constantly growing without check, will give

the appearance of one layer to the growth of two years. Notwithstanding this, practical men find counting the concentric circles of exogenous stems, to be the best mode which has yet been discovered for ascertaining their age, as in ordinary cases only one growth is made in the course of a year.

In tropical countries, where the temperature is comparatively speaking pretty much the same throughout the year, these rings are very indistinctly marked. In tropical countries, vegetation is not liable to that periodical check which it receives in colder regions, and therefore the cross-section of the stems of exogenous trees in many instances do not disclose these rings, or any separation of the wood into concentric layers.

As the same development of woody and cortical matter takes place in the branches as well as in the stems of exogenous trees, therefore, the time when a branch was first given off from the stem may be computed by counting the circles on the stem and branch respectively. If there are, for instance, thirty rings in the stem, twenty in one of its branches, and five visible on the cross-section of another, then the tree must have been ten years old when the first branch was developed, and twenty-five years of age when it formed the second.

If we carefully examine the rings on the cross-section of an exogenous stem, we shall soon perceive that they have not the same geometrical centre, that their breadth varies, and that they are occasionally thicker on one side of the tree than on the other. A variety of causes contribute to produce these effects. The variable breadth of the rings depends on the variability of the seasons; for more wood will necessarily be deposited when the season is favorable for vegetable growth, than when the contrary is the case. Moreover the circles will

be broadest on the side of the tree where there is the most wood deposited, and this is invariably on the side which contains the greatest number of branches and leaves. In a solitary tree, other conditions being favorable, the rings are generally the broadest on the south side of the stem.

The Duramen or Heart-wood.—We have already stated that the walls of the fully developed fibre-cells through which the sap circulates, become thickened by the deposition of matter in layers on their interior surface, until at length the cavities of the cells are almost entirely closed; when this happens, the sap can no longer permeate the walls of the cells, and their vital functions cease.

This solidification of the wood-cells is usually connected with a change in the color of the wood, more or less marked. Sometimes this change is made suddenly and without any intermediate shades, as in the wood of the ebony and logwood, of which the heart-wood is black or deep red and the alburnum almost white; but it frequently happens, that there exists no sensible difference of color between the alburnum and heart-wood, as for example, in trees with white wood, the color of the heart-wood never changing except from incipient decay.

This older, more solidified, and harder wood, which occupies the centre of the trunk, is the part principally valued by workmen as most suitable for economic purposes. The various fancy colored woods employed by the turner and cabinetmaker consist of the heart-wood only, which assumes different colors in different species, being black in the ebony, bright yellow in the barberry, purplish-red in the cedar wood, and dark-brown in the black walnut. The alburnum in all these trees, even in the ebony itself, is always white, and is regarded by workmen as a part of the tree of little or no value.

The ligneous zones, considered collectively, are more indurated towards the interior of the stem, because, in fact, these are the most ancient deposits; but, examined separately, they are more solid in their exterior than in their interior parts; because the latter was formed in early spring, at a period when the nutritive sap was more aqueous and less condensed.

The Medullary Sheath.—This is a very thin zone of vascular tissue and spiral fibre, immediately surrounding the pith, shown at *d d*. It may be readily seen in the traverse section of a young exogenous shoot by its green color, which appears deeper as contrasted with the white of the pith which it surrounds. If we scoop out the pith of the shoot from the ligneous cylinder which surrounds it, we shall obtain a longitudinal view of the medullary sheath, which will appear like a green layer on the interior surface of the cylinder. The medullary sheath is the earliest formed portion of the vascular system, and is developed with the upward elongation of the stem, sending its woody fibre and spirals into each young shoot and leaf to form its veins. The medullary sheath is the only part of an exogenous stem in which spiral vessels occur.

The Pith, represented at *a*, consists of soft cellular tissue, and is formed as the stem elongates. At first it abounds with nutritive matter, which serves to nourish the growing bud resting on its summit; this office fulfilled, it becomes dry and dies, assuming the appearance and structure of wood, insomuch that in old stems, there is scarcely such a thing as pith to be seen. Herbs and young shrubs, in proportion to their bulk, have more pith than trees. Many herbaceous stems expand so rapidly during their early growth that they become hollow, the pith being torn away by the distension and its remains

forming a mere lining to the cavity, as in grasses and other herbs.

A species of Æschynomene, growing in China, has the whole of its stem, which is about an inch thick, composed of a mass of pith, covered by a very thin epidermis. Rice-paper is procured from the herbaceous stem of this plant by the following process. The centre column of pith is cut spirally round the axis with a sharp instrument into a thin lamina, which is then unrolled, and may be made into sheets containing about a foot square. The medullary sheath and the concentric zones of wood are traversed by

The Medullary Rays.—These are numerous thin plates of condensed cellular tissue, which pass from the pith to the cellular system of the bark, and maintain a communication between them. These plates of cellular matter are to be seen on the surface of the cross-section of most exogenous stems, on which they appear as fine lines, radiating from the centre to the circumference, but cannot be traced continuously to any great extent in a vertical direction. The medullary rays constitute the silver grain of the carpenters. They are the remains of the cellular system of the stem, condensed into lines by the adjacent pressure of the woody wedges. The cellular system of the stem is first formed in a horizontal direction, and constitutes the matrix, or bed, into which ascends and descends, in a longitudinal direction, the fibro-vascular or woody system. The wood of the exogen is, in fact, made up of a number of wedges of longitudinal fibro-vascular tissue, embedded in the horizontal cellular tissue of the stem. The base of each wedge is in contact with the inner surface of the bark; the apex is next the pith and its sides are bounded by the medullary rays, which are, as before stated, the remains of

the horizontal cellular system, condensed by pressure of the longitudinal wedges into fine lines of cellular matter.

On the whole, the organization of an exogenous stem, considered collectively, presents three distinct systems, the cortical, ligneous and medullary system, or the bark, the wood and the pith; and from the mode of its development, it is evident that the wood has a constant tendency to solidify itself, and the bark to destroy itself; hence vitality soon ceases in the former, and the exfoliation and fall of the different parts of the latter, first the epidermis, then the suberous cellules, the cortical pith and even the liber.

The stem of an old exogenous tree, therefore, consists of a curious conjunction of dead and living matter, and the rings of wood not only mark the growths of successive years, but the number of generations of spontaneously grafted individuals which the stem has sustained. No part of such a tree is alive now that was living a few years ago. The leaves have fallen which the tree then bore, and the nodes from which they sprung are deeply buried in the interior of the stem, beneath the wood formed by the generations of buds and leaves that succeeded them; whilst the living bark that then covered the stem in immediate contact with the wood has been separated from it by the internal growth and deposition of other strata of bark, and is now visible on the outside of the stem in the form of dead and fissured layers, or else has been thrown off from its surface altogether. Thus in the coral tree, far beneath the ocean wave, where mineral matter assumes a vegetable form, the recent shoots and surface alone are alive, all is dead along the central axis.

CHAPTER V.

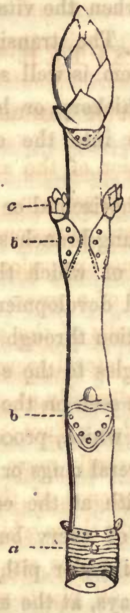
ON THE DEVELOPMENT OF THE BUDS AND BRANCHES.

THE stem or aerial portion of the axophyte possesses exclusively a force of lateral expansion, by means of which it projects into the atmosphere numerous dilated appendages, in the form of membranaceous expansions of its cells and fibres, more or less flattened, and of a green color, which are termed leaves. Certain definite cells of the axophyte appear to have a natural tendency to this lateral growth, and, therefore, these leaves are produced symmetrically at certain definite points on the stem called nodes (*nodus*, a knot;) so called because these parts of the stem are internally more solid and compact than the other parts, in consequence of the vertical fibres of the stem being interwoven with those which are sent off horizontally into the leaf. These nodes are very conspicuous in the bamboo, Indian corn, and all plants with hollow stems, which stems, on examination, will be found to be solid at these points. The naked intervals of stem between the nodes are termed internodes.

Before their expansion these leaves, together with the branches on which they are borne, are enclosed in a particular organ termed a bud. All branches begin and terminate in a bud. A bud is, therefore, clearly an undeveloped branch.

Now the bud, or undeveloped branch or stem, is made up of a succession of these leaf-bearing points or nodes, the internodes between which have not been developed, so that these nodes or leaf-bearing points are brought into close proximity,

Fig. 12.



A year's growth of the horse-chestnut branch, crowned with a terminal bud; *a*, scars left by the bud-scales of the previous year; *b*, leaf-scars, with round dots, showing the points of issue of the fasciculi, or bundles of woody fibre which form the petiole; *c*, axillary buds, developed at the base of the petiole of the fallen leaves.

and the leaves themselves developed in a rudimentary state, assume a scale-like appearance, and overlap each other symmetrically in accordance with their natural arrangement on the stem. The formation of buds is the natural result of the cessation of the growth of the internodes, and the partial development of the leaves at the nodes.

That the scales of buds are leaves in an imperfectly formed or rudimentary state, is evident from the fact that they are the

last leaves of the season, developed at a period when the sap is ceasing to flow, and when the vital powers of plants have become almost torpid. The transition of scales into the ordinary leaves of the stem is well seen in the spring, in the expanding buds of the hickory or horse-chestnut, where the gradual passage of one into the other may be distinctly traced.

Buds originate in the horizontal or cellular system, and may be distinctly traced in young branches to the pith or medullary rays, at the extremities of which they are invariably found when they take a lateral development. This may be easily verified by making a section through the centre of one of the lateral buds, at right angles to the surface of the stem, when the medullary ray will be seen on the surface of the section in the form of a white line, which, proceeding from the centre of the bud, traverses the several rings or annual deposits of wood, and terminates in the pith at the centre of the stem. The central cellular portion of every bud is therefore in direct communication with the interior pith of the young shoot by means of the medullary rays, at the extremities of which they are formed.

Buds are formed—some in the early part of the summer, others late in autumn, before the leaves fall from the trees—in the axilla of the leaves, that is, in the angle formed by the leaf-stalk and the stem. Examine the branch of any tree before it has cast its leaves, and you will find at the base of the petiole or leaf-stalk, the buds for the ensuing year. Hence in autumn, after the leaves have fallen, these buds remain attached to the branches.

Linnæus called buds the hybernaculum or winter residence of the branch; and the term is very appropriate, because it

expresses admirably the purposes for which the buds are formed.

The scales which envelope the bud are clearly designed to protect the embryo branch and leaves of the next season, which they surround, against the humidity and cold of winter. They vary in their texture, external covering, and thickness, in different plants. In the beech and lime tree, the bud scales are thin and dry; in the willow and magnolia, thick and downy, and in the horse-chestnut and balsam poplar, they are covered externally with a plentiful exudation of gummy resin, and thickly clothed internally with a woolly substance. By this beautiful provision both wet and cold are effectually excluded. Plants are most unquestionably a peculiar form of life, and when we see them thus modifying their organs to escape what is hurtful to their existence in the air, and constantly availing themselves in the development of their roots of what is conducive to their growth in the earth, we must admit them to be somewhat elevated in the scale of nature and very far removed from the conditions of inorganic matter.

In the Smilax rotundifolia, or common green brier, the buds are protected through the winter by the dilated and persistent base of the petiole or stalk of the old leaves, which remains on this shrub throughout the winter and falls away in the spring. In the Platanus occidentalis, or Plane tree, we seek in vain for the buds in their ordinary situation, the axils of the leaves, for they are protected during their growth, and are concealed within the swollen base of the petiole. This is well seen in autumn, when, on removing the leaf from the stem, the base of the stalk is found to form a cap or covering to the leaf buds.

Buds contain in their interior, in an embryo state, the whole

plan of the next year's growth, the nodes and even the leaves of the future stem. On the approach of winter the vegetable machinery stops, but there is no disarrangement of its parts, on the contrary, all is ready in the bud, and awaiting the stimulus of the returning light and heat.

The young leaves are beautifully folded together in the bud in such a manner as to occupy the least possible space, the peculiar mode varying in different plants. The arrangement of the leaves in the bud is termed their vernation or præfoliation. Any one can examine it in the spring with the certainty of being very much interested, by cutting across the leaf-buds with a sharp knife, when they are swelling and before they have begun to expand.

On the approach of spring, the leaf buds throw off their scales, and the leaves which were at first all crowded and closely packed together in the bud, become separated from each other by the elongation of their axis of growth, or the formation of internodes or naked intervals of stem between them, much after the mode in which the joints of a pocket telescope are drawn out one after the other; whilst, at the base, or in the axilla of every leaf-stalk, is seen to form, as the season advances, buds capable in their turn of being developed into branches, or a provision for the growth of the ensuing season.

Now it is the growth of the terminal bud which produces the elongation of the stem, whilst the development of the axillary buds produces the branches; and as the arrangement of axillary buds depends on that of the leaves, in the axils of which they grow, and as the bud is the germ of the future branch, it is evident that the development of the branches, together with all their subsequent ramifications, must follow

the same law as that which governs the arrangement and position of the leaves. If the leaves be opposite, the branches will be opposite; if the leaves be alternate, the branches will be alternate; and so on. This symmetrical arrangement of the branches is interfered with and obscured by the operation of the following causes:—

The non-development of some of the axillary buds.—As the primary plant is only called forth from seed by certain conditions of heat, light and moisture favorable to its development, without which it remains latent in the seed, so the branches only protrude from axillary buds when circumstances are favorable, otherwise the buds remain latent on the stem, and no branches proceed from them. Now many of the buds in the axils of the leaves do not grow; because their growth is checked by the rapid growth of some few leading buds, which monopolize all the nutriment, leaving them only just sufficient to carry them forward with the increasing thickness of the stem, and to maintain their position on its surface, where they remain ready for action in case the growth of the other buds is checked by untimely frost, or other causes. In this manner, trees, whose young and tender foliage and branches has sustained injury by the cold in early spring, soon become re-clothed with verdure. On this principle, also, trees are pruned and trained against walls, or other supports. Certain leading shoots and buds are cut, in order that the supply of sap they were monopolizing may flow to certain lateral and latent buds, and cause their growth in the proper direction. In general the sap has tendency to rise in greater force and abundance towards the extremity of the branches, the result of this is that the inferior leaves are the first to become detached from the branches, and their buds not receiving enough nourishment to bring them to

a perfect state, become abortive or incompletely developed. It is in fact almost always the inferior buds which are thus reduced to a rudimentary condition. The light does not get access to them so freely as to the buds towards the summit of the branches, and hence the lower part of the branches is generally naked and deprived of branchlets. The symmetrical arrangement of the branches with the leaves is also prevented.

By the growth of adventitious or irregular buds, that is to say, of buds which come in parts of the stem, between the leaves, and not in their place in the axils of the leaves. Sometimes, owing to the growth of the leading buds, the growth of the latent axillary buds is checked altogether, in which case they sink beneath the surface of the stem, and are buried beneath the succeeding layers of wood; but their vitality is not destroyed so long as they remain at a certain depth in the stem, that is to say, in the alburnum or sap-wood. The trunks and branches of trees, therefore, always contain an immense number of these buried buds, and should some of the leading branches be broken off by high winds, or sustain injuries from other causes of this character, then the flow of sap to them becomes so powerful that they will force their way through the wood to the surface, although that wood be the successive growths of years, and break forth into branches. All must be familiar with the sight of willows and other trees, whose main branches have been thus broken, and whose trunks have, nevertheless, been covered with young branches and shoots, the growth of buds which have been buried in their wood, and for years dormant beneath their surface.

From these facts it is plain that those forms of life which we call plants, although rooted to the soil, and more exposed by this circumstance than any other living being, are nevertheless

far from being destitute of a power to escape. It is true that they are exposed to the inclemency of the season, and are threatened with destruction on every side, but so powerful and varied are the defences with which nature has furnished them, that they seem to be all but indestructible. How innumerable are the buds with which a tree is covered! How complete their protective apparatus against the winter's cold! We have seen that each bud, although it remains in union with the parent tree, is nevertheless capable of forming the germ of an independent life. If not developed, it only awaits the destruction of its associates to enter the breach, repair the injury, and continue by its growth the battle of the living principle in the plant against the hostile forces of nature. Endowed with such powers of defence, a tree will grow and lift its majestic and massive stem for centuries to the air and light of heaven, and if after thus long and bravely conflicting with nature, it should be finally prostrated by the power of the tempest, if its connection with the soil still continues, the reserved and buried buds of other years shall issue forth a new phalanx of defence, and renew successfully the struggle of the plant for life.

CHAPTER VI.

THE LEAVES.

LEAVES are contrivances by which the green absorbent surface of the plant is increased, so that the greatest practicable amount of food is taken from the air. The entire structure of the leaf proves it to be put forth for this purpose.

The leaf is simply an expansion of the green cellular bark of the young shoot, and is formed by the spread of the woody fibre which issues from its side, carrying with it at the same time the bark, which thus becomes expanded horizontally to the air and light of heaven.

When the leaf is fully developed it consists of two parts, viz.: the expanded portion called the lamina or blade, and its little stalk or support, which is termed the petiole. Sometimes, however, the petiole is wholly absent from the leaf, the spread of the woody fibre, together with the expansion of the green young bark of the young shoot, taking place at its surface. In this case the leaf is said to be sessile. So also this expansion of bark does not always take place at a single point of the stem, but is extended down the stem a little and then spreads out horizontally, producing a decurrent leaf. The leaves of the Verbascum thapsus, or common mullein, are of this description. Occasionally, as in the orange, the bark of the petiole itself shows this tendency to expansion, when the petiole is said to be winged. Most frequently, however, distinct fasciculi or bundles of woody fibre and spiral vessels emerge from the side of the shoot, unite and form a petiole,

and then diverge at some distance from the stem, forming the expanded lamina of the leaf. The points of the stem from which these fasciculi have issued are apparent on the scars left by the fallen leaf stalks in the form of round dots, of a uniform number and arrangement in each species of plant. Thus in the apple, the pear, and the peach, the leaf is attached to the stem by three fasciculi or bundles of woody fibre, and three round dots may be distinctly seen on the leaf scar; and in the horse-chestnut, from five to seven dots are visible on the leaf scar, the number of fasciculi passing out of the stem and uniting in the petiole being the same as the number of the leaflets.

The vascular or woody system which passes out of the stem into the leaf is clearly designed to give to it the needful strength and support, as well as to convey the sap to be aerated in the leaf. This part of the leaf evidently constitutes its framework or skeleton. The vascular and woody system in exogenous leaves, as for example, that of the Cornus florida, or Flowering dogwood, consists of a distinct midrib or keel, and less elevated ribs, (*costæ,*) which proceed from the sides of the midrib and take a curvilinear direction to the margin and apex of the leaf. On closer investigation the costæ are seen to communicate with each other by means of small transverse fibres, which again branch and subdivide in various ways, the last ramification or branchlets running together or anastomosing amongst themselves, and the whole forming a delicate and beautiful network.

Seen through the microscope, this vascular framework is found to consist of woody fibre enclosing spiral vessels. This is its constitution, from the main fasciculus or bundle of woody fibre called the midrib or keel of the leaf, through the several fasci-

culi or costæ which proceed from the sides of the midrib, each fasciculus consisting of woody fibre enclosing spiral vessels throughout all its ramifications.

The cellular system of the leaf.—This substance forms its principal part, filling up the meshes in the network, formed by the vascular system. To the naked eye it appears as a structureless pulpy mass of a green color, called parenchyma (*παρα*, beside or between, and *χεῦμα*, anything effused or spread out.) Under the microscope the parenchyma of the leaf no longer appears as an unformed mass, but as a beautiful and regular arrangement of cells, which are so disposed as most effectively to subserve those purposes of nutrition for which the leaf is formed.

In all leaves which present one surface to the sky and the other to the ground, there is between the upper and under cuticle two strata of parenchyma differently arranged. In the upper stratum of parenchyma, the cells are arranged in one or more compact layers, vertically, or at right angles to the upper surface of the leaf, so that they present the least possible

Fig. 13.

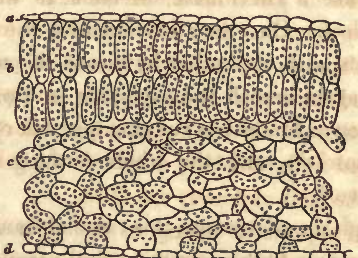


Fig. 13. Magnified view of the edge of a leaf. The parenchyma is alone represented, the woody tissue being left out. *a* and *b*, show the epidermis and denser parenchyma of the upper surface of the leaf; *c*, *d*, the looser parenchyma and epidermis of its lower surface.

amount of surface to the sun; whilst, in the lower stratum of parenchyma, the cells are arranged horizontally, having amongst them numerous intercellular passages, or cavities filled with air, which communicate freely with each other through the substance of the leaf, and with the external air by means of the stomata or pores in the epidermis.

The dense parenchyma of the upper surface of the leaf accounts for its deeper tint, and is well adapted to restrain the excessive evaporation to which the fluids in the upper stratum of cells are liable, by their direct exposure to the sun; whilst the loose parenchyma of the lower surface is the cause of the lighter tint of the underside of the leaf, which, together with the pores of the cuticle, is well calculated to give the air free access to all parts of the leaf, from which source plants derive the greater part of their nutriment. Leaves growing erect possess uniformity of structure in both strata of parenchyma.

The vegetable membrane which forms the walls of the cells of the parenchyma, is perfectly white and colorless. The green color of the leaf is found to be caused by the formation of granules of green matter in the cells, which either float free in the sap contained in their cavities, or else collect into grains and adhere to the walls or sides of the cells. This substance is called chlorophyl (χλωρος, green, and φύλλον, a leaf), in contradistinction to chromule (χρῶμα, a color), which is the term employed by botanists to designate the colored substances with which the cells of flowers are filled.

Chlorophyl appears to belong to the class of waxy bodies. It is soluble in alcohol or ether, but not in water, and is developed only in those cells which are exposed to the action of light. It is therefore only formed in the superficial strata

of cells. Chlorophyl is not developed in the external investing layer of cells called the epidermis, nor in the woody fibre through which the crude sap circulates, both the epidermis and woody fibre being from this cause white and transparent; but it is formed in the superficial strata of cells immediately beneath the epidermis, and gives to the leaves and young shoots their green hues.

That the chlorophyl, or green matter in plants, is produced by the effect of light, is evident from the fact that it is decomposed and disappears when plants are made to grow in the dark. The celery served at table is blanched or rendered white by covering the stems with earth, so that the light cannot gain access to them; and for the same reason, plants exposed to the full sunshine have a deeper tint than those which grow in the shade.

The epidermal system of the leaves, together with the valvular action of their pores has been already described, (page 22,) and we have seen how beautifully their stomata control the evaporation from their surface. But these organs have other uses. They are the instruments by which the leaves communicate directly with atmosphere, and by which vegetable breathing or respiration is carried on. Vegetables respire as well as animals, and the sap of plants which is analogous to the blood of animals, must be brought into contact with the atmosphere, like the blood, and be thoroughly aerated in the leaves, before it can be converted into nutritive fluid.

Bonnet was the first who observed that leaves, when plunged into water and exposed to the action of sunlight, disengaged gas. He also found by experiment, that the same amount of gas was evolved when the leaves were immersed in water which had been previously boiled, and therefore completely

deprived of its air. The gas was therefore clearly evolved by the leaves. Priestly recognized this gas to be oxygen, and Ingenhouse showed that light was indispensable to its manifestation, since it ceased to evolve itself from the leaves in darkness. Such was the state of the question when Sennebier fully demonstrated by experiment, that the oxygen evolved from the leaves was the result of their decomposition of the carbonic acid which was contained in them.

This carbonic acid is chiefly abstracted from the atmosphere by means of the stomata or pores of the leaves. Every one must be aware that neither plants nor animals could live without air, and if they both lived on the same air, the atmosphere would soon become unfit for respiration. But the air taken into the lungs of animals in the act of inspiration, imparts its oxygen to the dark venous blood in the lungs, which combining with the carbon of the blood forms carbonic acid; this gas is expelled from the lungs in the act of expiration (*ex*, out, *spiro*, to breathe.) The blood thus oxygenated by breathing, loses its dark color and is changed into that bright red arterial stream which again circulates through the system for its nutrition. Now the atmosphere would soon be thoroughly poisoned by animals, but for the purifying influence exerted on it by the vegetable creation. Carbonic acid, CO2, which is composed of one equivalent of carbon and two equivalents of oxygen, is taken into the plant through the pores of its leaves, and under the influence of solar light decomposed, the plant fixing the carbon, which when thus assimilated, forms the chlorophyl or green matter in them; whilst the oxygen is set free and escapes into the atmosphere, which gas is the food of animals.

This inspiration of the carbonic acid of the atmosphere,

together with the assimilation of the carbon and the expiration of the oxygen, constitutes what may be truly denominated vegetable breathing or respiration.

These results take place only when the plant is exposed to the direct rays of the sun. Recent experiments have shown that the process ceases when the sun is behind the clouds, and that not only during the night, but even under the influence of diffused daylight, the exhalation of oxygen is stopped.

The exhalation of oxygen gas from the leaves of plants is the only provision that we know of for keeping up its supply in the atmosphere. The prevailing chemical tendencies are to take oxygen from the air. Were it not for the copious supplies of this gas poured into the atmosphere from the pores of plants, animal life could not exist. Hence the perfect adaptation of the two kingdoms of nature, each removing from the atmosphere what would be noxious to the other, each yielding to the atmosphere what is essential to the life of the other.

To show that plants give out oxygen in sunshine. Fill a jar with water, and invert it in a vessel containing the same fluid. Introduce beneath the jar a sprig of mint, or any other living plant. After a while bubbles of gas will collect on the leaves and ascend to the top of the jar, displacing the water. If the air thus collected be tested, it will be found to be pure oxygen gas. If the vessel be placed in the shade, the bubbles of gas will disappear from the leaves.

The leaves are not the only organs of vegetable respiration. The young branches, the scales, in a word, all the herbaceous and green parts of plants act on the atmosphere in a similar manner to the leaves. They take in carbonic acid from the atmosphere, assimilate the carbon, and give out the oxygen.

Form of Leaves.—It has been stated that the leaf of a plant

is simply an expansion of the wood and bark of its stem, the wood issuing from the side of the shoot whilst in its green young state in fibrous bundles, which carry with them at the same time the green cellular bark of the shoot, and then by their expansion spread it out to the air and light of heaven. There must, therefore, be a natural adaptation and correspondence between the spread of the woody fibre which constitutes the framework of the leaf, and the peculiarities of its form. This idea was first suggested by Decandolle. According to him, the shape of leaves depends on the mode in which the fibres diverge when they leave the side of the shoot, and upon the quantity of parenchyma or bark which they carry with them; and by him this arbitrary nomenclature of form was rendered intelligible and reduced to something like system based on scientific principles. Decandolle distinguishes three principal modes in the venation of leaves, viz.: the net-veined, the parallel-veined, and the fork-veined.

1. *The reticulated or net-veined leaves* are characteristic of exogens, which are justly regarded as the most highly organized plants in the vegetable world. Two modifications of net-veined structure have been observed, the feather-veined and radiate-veined; the leaves of the chestnut are good examples of the former, and those of the garden nasturtium of the latter. The margins of net-veined or exogenous leaves are very seldom entire, but most frequently notched in various ways, described in books as dentate or toothed, crenate or scolloped, serrate or having teeth like a saw, of which last we have a good example in the leaf of the rose. The cause of these incisions has not been clearly ascertained.

2. *The parallel-veined leaves* are the distinguishing feature of endogens, which are considered humbler in their organic

structure. That nature has been less elaborate in their formation, will be evident to any one who will only take the trouble to compare a lily leaf with that of a rose. If held up to the light, the intricate and highly complex ramifications of the fibrous structure of the exogenous leaf of the rose will be seen in striking contrast with the extreme simplicity of the endogenous leaf of the lily. Two different modes of venation have also been noted in endogens, the curve-veined and the straight-veined. In the first instance, the veins run in parallel curves from the base to the apex of the leaf, and in the other case proceed in right lines. The plantain and Hemerocallis or day-lily, are good examples of the first, and grasses of the last method of venation. The margin of endogenous leaves is invariably entire, and never marked with indentations of any kind.

3. *The fork-veined leaves,* which are peculiar to ferns, plants still lower in the scale of organization. It may be proper to qualify these divisions and sub-divisions, by remarking that they are not intended accurately to define the boundaries between the different modes of venation. There is an approach to the forked method of venation in some exogenous plants, as in clover, and doubtless there are many intermediate forms. All classification is but an approximation to that order which obtains in nature. All that Decandolle intended, was to point out some of the principal modes in which the woody matter of leaves was distributed through their parenchyma, and to call attention to the fact that the variety of their form is the result of one or the other of these modes of distribution. The student will now understand that leaves assume the linear, lanceolate, ovate or orbicular form, according to the greater or less degree of divergence of the woody fibre constituting their framework.

Simplicity in causes and variety in effects mark all the operations of nature!

The distribution of leaves about the stem.—All who notice plants much have frequently observed the regularity and symmetry with which leaves are arranged around the stem. Sometimes they spring from its sides in pairs, crossing each other at right angles, as in the mint family, or in beautiful whorls, as in the Galium or bedstraw tribe; and again, they are scattered along the stem on either side, but still with an apparent regularity, and certainly not at random. These peculiarities of their distribution are produced by a combination of the two following causes.

1. *The manner in which the stem grows.* If the elongation of the stem and the growth of the leaves be simultaneous, the leaves will be scattered on all sides of the stem, and will be few or numerous, according to the greater or less degree of rapidity with which they are developed; but if the elongation of the stem is periodically checked, and the growth of the leaves at the same time continues, they will necessarily start out from the same point of the stem in pairs or in whorls, according to the length of time taken up before the stem again elongates. This is well seen in Lysimachia quadrifolia, which in ordinary circumstances bears whorls of four and six leaves; these, when the growth of the stem is rapid, become alternate. We have also instances of the operation of this law in the Coniferæ, or pine family. The Larch has leaves developed in fascicles or bundles. These leaves are without any lamina or blade, rigid and needle-shaped or linear. They are brought together in consequence of their rapid development and the non-elongation of their axis of growth. That this is really the cause of their fascicled character, is evident on close

inspection of the young shoots of the larch, which by their rapid growth do not admit of any fascicular development of their leaves. On these shoots the young leaves of the larch will be found to be scattered, not fascicled, clearly showing their natural arrangement, and proving that the fascicles are the result of the development of the leaves and the non-development of the nodes of the stem.

The spiral growth of the leaves. This is most readily perceived in such plants as have their leaves distributed alternately on either side of the stem. If a thread be wound about the stem so as to touch the basis of the first, second, third, fourth, and succeeding leaves, it will be found to describe an ascending spiral around the stem, and with such accuracy that the law may be expressed numerically. The observations of Dr. Gray, on leaf arrangement, are too interesting to be omitted in this place. "If we write down in order the series of fractions which represent the simpler forms of leaf arrangement, as determined by observation, viz.: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{36}$, we can hardly fail to perceive the relation that they bear to each other. For the numerator of each is composed of the sum of the numerators of the two preceding fractions, and the denominator of the sum of the two preceding denominators. Also, the numerator of each fraction is the denominator of the next but one preceding. We may carry out the series by applying this simple law, when we obtain the farther terms, $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, $\frac{21}{55}$, &c. Now these numbers are those which are actually verified from observation, and, with some abnormal exceptions, this series comprises all the cases that occur."

That the interest which attaches to the above extract may be fully appreciated, I remark, that the fractions severally

represent different kinds of spirals, the numerator denoting the number of times that the thread winds round the stem before it touches the base of a leaf directly over the one it began with, whilst the denominator expresses the number of leaves it touches in its course, before it arrives at that leaf thus situated. Thus the fraction $\frac{2}{5}$ denotes that the thread winds twice round the stem, covering the bases of five leaves in its course; consequently, the sixth leaf stands directly over the first.

But the most curious and wonderful thing is that the higher fractions $\frac{5}{13}$, $\frac{8}{21}$, &c., as developed by the application of this numerical law, are positively realized in nature. For the same principle of arrangement extends to all those parts of plants which are modifications of leaves, and these numbers are actually verified when we come to examine the rosettes of the houseleek, and the scales of pine cones. It is the combination of both these causes, the tendency to spiral development, combined with the peculiarities of stem growth, which disposes the leaves of plants with so much regularity and symmetrical beauty around their stems.

Leaves sometimes assume very curious forms.—Sometimes the lamina or thin expanded portion of the leaf becomes nearly or altogether abortive, and the petiole itself assumes a leaf-like appearance. This modification of structure is termed a phyllodium. The leaves of the New Holland acacias are all more or less formed into phyllodia. These plants have compound pinnate leaves, and just in proportion as the pinnæ of the limb are suppressed, is their petiole expanded and leaf-like. In young acacias, and occasionally in old ones which have been freely pruned, all the intermediate states between a compound pinnate leaf and a simply expanded petiole may be observed.

Decandolle considers that the sheathing leaves of endogenous plants which are not furnished with a distinct limb, are only expanded petioles. The leaves of the Hyacinth, and Iris versicolor, or common blue flag of the pools, are of this nature. Such leaves are sometimes met with even in the higher order of exogenous plants, as, for instance, Ranunculus flammula or Spearwort crowfoot, a common aquatic plant.

Sometimes the edges of the lamina or blade cohere together, producing still stranger modifications of leaf structure. It is well known that the parts of plants which grow closely together, are apt to become coherent. Accidental unions of this kind amongst the leaves of plants are of common occurrence. In some species these unions occur after the plant is considerably grown, as in the garden honeysuckle, the upper leaves of which usually cohere together by their bases, owing to their sessile character, and form what botanists call a connate leaf. So also, the numerously crowded and closely compact leaves, constituting the calyx or cup of the Marygold or Hollyhock flowers, will be found to be more or less united with each other. In other instances, where the cohesion of the leaves with each other or with the stem is of constant occurrence in every stage of vegetable development, this union appears to take place at a much earlier period. In this case, whilst the plant lies folded up within the seed and its texture is yet delicate, the numerous vessels of its organs which are thus brought into close contact anastomose; that is, run together or unite with one another by means of the elaborated juices which nourish them, thus producing those cohesions of the parts of plants which are visible in their after developments.

If these views be correct, they will serve to explain the nature of the hollow leaves of Sarracenia purpurea, or the side

saddle flower, with its leafy cups half filled with water and dead insects, which abounds in the bogs of the Northern and Middle States. This pitcher may be conceived to be formed by the cohesion of the edges of a partly formed phyllodium. If we imagine a dilated petiole with its partially formed lamina to curve over and unite at its edges, a leaf like that of the Sarracenia will evidently be formed, in which the pitcher will be simply a hollow petiole, whilst the hood at its summit is produced by its abortive lamina or blade.

In Utricularia, or bladderwort, the leaves form sacs called ampulla, which are filled with air, and float the plant in the water at the time of flowering.

But the most remarkable case of leaf cohesion, is seen in the Nepenthes distillatoria, or pitcher plant of the East Indies. In this instance, the petiole when it first leaves the side of the stem, is round, or of its usual shape, then it expands into a leaf-like organ or phyllodium, and next it is contracted into a tendril, finally it forms into a phyllodium, the sides of which cohere together so as to form a pitcher, which is surmounted at the summit by the abortive lamina or blade, in the shape of a lid. This pitcher is constantly filled with about half a pint of pure water, which is not collected from without, as in the Sarracenia, but is secreted by the plant: for the lid surmounting their summit constantly and accurately closes the orifice of these pitchers, and their internal surface is of a glandular structure. In Ceylon, where this plant is common, it is called by the natives by a word the signification of which is monkey cup; because these cunning animals when thirsty, and there is no stream at hand, open the lid and drink the contents. Men also travelling or hunting in the woods, often find the water contained in these vegetable pitchers a means of assuaging their thirst.

The fall of the leaf.—There is no subject on which botanists have entertained a greater variety of opinion than on the fall of leaves. The causes which produce their excision from the stems and branches of plants are so exceedingly complicated, that a much more advanced condition of botanical science seems to be necessary before they will be clearly and accurately understood. It is obvious that leaves are thrown off by plants because they are no longer of any service to them, and the means by which nature effects their separation are truly wonderful, and at the same time instructive.

The causes which produce the decay and fall of leaves are partly chemical and mechanical. The water which enters the roots of plants as it percolates the soil, dissolves a small portion of earthy matter. This is partly deposited in the woody and fibrous tissues of the stem, but principally in the cellular tissue of the leaves, by the evaporation which is continually taking place at their surface. In this manner the interior walls of the leaf cells become encrusted or thickened by deposits of mineral matter, just as earthy matter accumulates at the bottom of a pot used for culinary purposes, and the leaf is thus rendered finally unfit for the performance of its functions. The mineral matter deposited in the cells is sometimes beautifully crystallized, the earths or bases taken up by the roots uniting with the acids formed in the vegetable organs. The most common kinds of crystals are those of the carbonate and oxalate of lime which are of different sizes and forms, rhomboidal, cubical and prismatic; but the most prevalent form is the acicular or needle-shaped. It is to this form that the term raphides (*raphis* a needle) was originally applied by Decandolle, although it is now used indiscriminately in reference to all cellular crystals.

In the autumnal months, the light becomes less powerful, the

leaves lose their green color, and their cells becoming gradually and entirely choked up with mineral matter, the sap no longer circulates through them. They absorb oxygen from the air, and the result of their different degrees of oxidation is seen in all that variety of autumnal tint, which casts such a charm over the dying landscape.

Whilst these chemical changes are taking place, nature is at the same time preparing to effect the mechanical excision of the leaf from the plant.

Now, at first, all leaves are contiguous with the stem. As they grow, an interruption of their tissue takes place at the base of their footstalk, by means of which a more or less complete articulation is formed. This articulation is produced by the continuation of the growth of the stem after the leaf has attained its full growth, which it generally does in a few weeks. The growth of the leaf being completed, all its functions languish in consequence of the increased deposition of mineral matter within its cells, and the base of the petiole or footstalk being no longer able to adapt itself to the increasing diameter of the stem, a fracture between the base and stem necessarily ensues; the excision advances from without inwards, until it finally reaches the bundles of woody fibre, which are the main support of the leaf.

Whilst, however, nature is forming a wound, she is at the same time making provision to heal the same; for the cuticle or epidermis of the stem is seen to grow over the surface of the scar, so that when the leaf is detached the tree does not suffer from the effects of an open wound. The provision for separation being thus completed the leaf is detached by the growth of the bud at its base, by the force of the winds, or even by its own weight. Such is the philosophy of the fall of

leaves, and we cannot help admiring the interesting and wonderful provision by which nature heals the wounds even before they are absolutely made, and affords a safe covering from atmospheric changes before the parts can be subject to them.

The decay and fall of leaves is, therefore, not the result of frost, as is commonly supposed, for leaves begin to languish and change color (as happens with the red maple, especially,) *and even fall*, often before the autumnal frosts make their appearance, and when vegetation is destroyed by frost the leaves blacken and wither but remain attached to the stem; but the death and fall of the leaf is produced by a regular vital process, which commences with the first formation of this organ, and is completed only when it is no longer useful. There is no denying, however, that the frosts of autumn, by suddenly contracting the tissues at the base of the petiole, accelerate the fall of leaves. All must have noticed, on a frosty morning in autumn, that the slightest breath of air moving amongst the decayed and dying leaves, will bring them in complete showers from the trees to the ground.

In general, we may say, that the duration of life in leaves is inversely as the force of the evaporation which takes place from their surface. For we find that the leaves of herbaceous plants, or of trees which evaporate a great deal, fall before the end of the year, whilst the leaves of succulent plants, or of evergreens, which latter are of a hard and leathery texture, and evaporate but little, often last for several years. In pines, firs, and evergreen trees and shrubs, there is an annual fall of leaves in the spring of the year whilst the growth of the season is taking place; but as this leaf-fall is only partial, consisting of one-half or one-third at a time, there is always a sufficient number left on such trees to keep them clothed with

perpetual verdure. Hence it is, that the entire foliage of such trees consists of leaves which have been attached to the stem from one to three or five successive years.

In the beech and hornbeam, the leaves wither in autumn, and hang on the branches in a dead state through the winter. Such leaves, when examined, will be found to be contiguous with the stem at the base of their petiole, and therefore without that articulation or joint which so materially aids in the disruption of the leaf from the stem. These dead leaves fall off when the new leaves expand in the spring.

Most of the trees of this country have deciduous leaves, and in winter our woods are bare and no longer cast their shadows on the earth; but the forests of tropical climates are evergreen, and usually retain the same appearance throughout the year. A perpetual shade is thus afforded by nature, which in some measure gives relief against the continuous heat of these regions.

CHAPTER VII.

ON THE NATURE AND SOURCES OF THE FOOD ASSIMILATED BY PLANTS.

THE investigation of the nature and sources of those substances assimilated by the nutritive organs of plants, is necessary to a clear understanding of their physiological action, and will very properly close this part of the subject.

These substances can only be determined by chemical analysis. Plants have been examined chemically by Liebig, Mulder,

and Johnson, and we are about to lay before the student the results of the labors of these philosophers.

The solid part of plants, chemically considered, is found to consist of organic and inorganic matter; the first may be burnt away and is derived from the atmosphere, the second is incombustible and is derived from the soil in which the plant grows.

To show the organic and inorganic matter in plants. Burn a piece of wood or straw in the flame of a lamp. The part which burns is organic matter and passes again into the atmosphere from whence it was taken; the incombustible ash that remains is the inorganic matter in the plant, which was derived from the soil.

The organic part of plants is composed of four substances, carbon, or charcoal, more than one-half, oxygen one-third, hydrogen one-twentieth, and nitrogen one-fiftieth.

The inorganic part of plants, or the ash remaining after the combustion of the organic matter in them, consists of no less than eleven different substances, viz: potash, soda, lime, magnesia, silica, oxide of iron, oxide of manganese, sulphur, sulphuric acid, phosphoric acid, and chlorine.

The carbon or charcoal in plants composes more than one-half of their entire bulk. If a green leaf or a piece of wood be charred (which may be done by heating it in a close vessel out of contact with the air,) all the hydrogen and oxygen in the plant will be driven off, and what remains will be the amount of carbon in the plant, together with a small percentage of inorganic matter. The leaf or specimen of wood which has been thus carbonized will be found to preserve its form and bulk uninjured, even to that of the most delicate cells and vessels, but will be considerably lighter. A piece of common stove charcoal is a beautiful instance of wood which

has been thus treated, and evinces that charcoal is the principal constituent in the material out of which a plant is constructed.

The carbon found in plants is derived from the atmosphere and from the decomposing vegetable matter in the soil. It has been shown how plants take in carbon from the atmosphere, through the pores of their leaves, in the form of carbonic acid gas. But the atmosphere is not the only source; the soil also contains an immense quantity, for carbonic acid is given off not only by the lungs of animals, but by burning bodies, and by the decaying animal and vegetable matter in the soil.

When we burn a plant and thus effect a separation between its organic and inorganic constituents, restoring the former to the atmosphere and isolating the latter under the form of ashes, the process of combustion is only the result of the rapid union of the oxygen of the air with the carbon in the leaf, and the consequent formation of carbonic acid gas. Now precisely the same process occurs in nature when plants decay and disappear from the earth's surface.

The decay of vegetable bodies in the soil, as Liebig has shown, is only a slower process of combustion, being produced by precisely the same cause, viz., the union of the oxygen of the air with the carbon in the plant, with the consequent production of carbonic acid gas.

Hence we see the reason why wood when it gradually decays becomes brown and ultimately black, presenting precisely the same appearance as if it had been burnt with fire.

In the process of decay, or as it is termed chemically, *eremacausis*, that is slow burning, the oxidation of the vegetable is so slow that neither heat nor light is evolved; hence the products of the vegetable decomposition are aqueous as well as gaseous, or the body, popularly speaking, putrefies.

To this decaying animal and vegetable matter the term humus is applied. It constitutes the brown or black portion of every soil. Wherever it exists, there plants spring up the most readily, whilst in places devoid of it, they are stunted and dwarfed in their growth and decidedly inferior both in organization and beauty. Thus, though carbonic acid is principally absorbed from the air by the leaves, the roots of plants also find it in every soil which contains humus; for humus consists in decaying organic matter, that is, organic matter resolving itself by a sort of slow combustion into carbonic acid and water.

Carbonic acid makes up, on the average, only one two-thousandth part of the bulk of the atmosphere. It is, however, very soluble in water, and its accumulation in the air like that of ammonia is mainly prevented by the rains which greedily absorb and wash it down to the earth, from whence it is imbibed by the root. In this manner carbonic acid enters the system of the plant by the roots as well as by the leaves.

Hydrogen and the greater part of the oxygen enter the plant by the roots in the form of water (H_2O), which consists of these two gases in chemical union. These two gases indissolubly bound together in the form of water, which circulating through nature on entering the system of plants, is nevertheless readily decomposed by the powers of vitality.

Nitrogen enters by the roots chiefly in the form of nitric acid and ammonia. The former is produced during the passage of electricity through the air; the latter is copiously evolved from compost heaps and from decaying vegetable and animal matter.

To test the presence of ammonia in the compost heap. Dip a glass tube in hydrochloric acid (spirit of salts) and hold it

over the heap. If ammonia be present, copious white fumes will be perceived, which result from the chemical union of the hydrochloric acid gas with the ammoniacal gas, and the formation of a salt, the hydrochlorate of ammonia, or the sal ammoniac of the stores. NH_4Cl

Although ammonia is constantly rising in vast quantities into the atmosphere from decaying animal and vegetable matter, it is nevertheless easily soluble in water, and is therefore prevented from accumulating there by the aqueous vapor of the atmosphere, which, when it is precipitated thence in the form of rain, conveys the ammonia in solution to the roots of plants. That this is the fact is evident because ammonia can be detected in rain water and in the sap of plants, and also because all manures such as guano, which contain a great amount of ammonia, are found to be fertilizing to soils.

The combustible or organic part of the plant forms by far the greater part of its structure. This is evident from the small amount of ash or inorganic matter left after its incineration. It follows that plants derive the materials of their growth mainly from the atmosphere.

That certain plants derive the greater part of their food from the atmosphere, affords an explanation of the process by which nature changes the barren rock into the fertile soil. The first plants which clothe the surface of the newly formed coral reef, or of our common rocks, are lichens and mosses; plants which derive the greater part, if not the whole of their nutriment, entirely from the atmosphere. Now plants can only grow in proportion to the quantities of food afforded them. Lichens and mosses are plants of very humble growth and exceedingly simple structure, consisting of, comparatively speaking, only a few cells. Successive generations of these

atmospheric cryptogamia flourish and die, forming a humus for the growth of grasses, ferns, and more highly organized plants; until at length there is formed on the surface of that once barren rock a sufficiency of humus for the nutrition of all the varieties of vegetable organization found in the fertile meadow, the tangled thicket, and the widely extended forest. Finally man comes to take possession of the new domain which nature has thus been carefully preparing for him, and life reaches its highest stage of development.

The inorganic matter constituting the ash which remains after the combustion of the plant, is wholly absorbed from the soil, and enters the plant in a state of solution by the pores of the roots. Some persons have supposed that these mineral matters were produced by the plants themselves, and not derived from without. It is true that the earths, such as silica or sand, alumina or clay, are insoluble by themselves in water, and that the subdivision of the matter of which they are composed must be carried to an almost infinite degree of minuteness, before they can pass into the system of the plant through the minute pores of the roots; but all the earths are soluble with the alkalies, such as potash, which enters largely into the composition of all rocks, and as these earths are furnished to the soil by the slow decomposition or disintegration of rocks, there can be no doubt that the water, as it percolates the soil impregnated with potash and carbonic acid, effects their solution to such an extent that they pass unimpeded into the system of the plant along with the water which is imbibed by the root.

Each species of plant, according to its peculiar constitution, retains a greater or less amount of one or more of these earthy ingredients. Thus, nearly all plants retain a quantity of potash; wheat, a certain amount of silex; some aquatic plants

accumulate iron so that on decaying they leave a sediment of iron rust in the water; chlorine is found in all marine plants; phosphorus in the onion; and sulphur in mustard seed, in celery, and in ginger. The immense quantities of water variously impregnated with these foreign bodies, which pass through a plant, being condensed by evaporation in the leaves, is sufficient to account for their presence, in appreciable quantities in the plant, however minute may be their proportion in the water which the roots imbibe. Hence it is found that plants will not grow in distilled water, or water freed from all foreign ingredients; and also that the water exhaled by plants is so pure that not a trace of foreign matter is discoverable in it; the stomata or pores of the leaves are in fact the most perfect stills in the great laboratory of nature. About two-thirds of the fluid taken up by the spongioles of the roots, is evaporated from the leaves of plants in the form of water, and consequently about one-third remains in the plant in a highly concentrated state, and contains the carbonic acid and other earthy ingredients which happen to be dissolved in the fluid when first presented to the roots.

Although the ash or inorganic matter in plants constitutes a very small proportion of their substance, yet its importance is not on this account to be underrated. The small per centage of inorganic matter contained in them appears to be absolutely necessary to their healthy growth. It is for this reason that the soil exercises such a marked influence on the distribution of species. It is impossible to examine the plants which spring up spontaneously in any district, without arriving at the conclusion that they are influenced in the development of the peculiarities of their organization, by certain inorganic matters which abound in the soils in which they grow. The barren mountain

and the fertile valley, the sandy soil and the marshy swamp, the margin of rivers and shores of the ocean, have all their peculiar species of plants. The chemical composition of the ash of a plant being known, scientific conclusions can be drawn as to the soil most suitable for its growth.

A good soil must contain all the substances found in the ash of the plant. This is a matter of great importance to the agriculturist. If we give abundant and vigorous food to an animal it becomes strong and fat; if its food be small in quantity and poor in quality, it becomes poor and lean. Just the same happens to a plant. Plants will grow vigorously and fruit plentifully when there is an abundance of that kind of food in the soil which is the most suited to their organization; and their growth will be checked and their fruit injured by any deficiency in their proper food. Nature is a wise and perfect cultivator. Some plants are found in a moist soil, others in a dry one. Some seek the cool shade, others the warm sunshine; some are natives of lofty and barren mountains, others of lowly and fertile valleys; some fixed to rocks delight in the noisy waves of the sea; others attached to stones in brooks and rivers grow beautifully in their quiet waters. All plants, however, are placed by nature in soils which are chemically and physically adapted to promote their growth, so that they may answer her grand and secret purposes in the development of their organization.

The motion of the sap in plants.—The function of nutrition, which in the higher animals comprises a variety of distinct processes, is reduced in plants to the utmost degree of simplicity. When water charged with nutritive substances from the soil enters the cellular extremities of the roots, it immediately fills the cells and vessels of the plant, and becoming subjected

to their vital action, undergoes a change of properties. The water thus altered is called the crude or ascending sap. This fluid, in the active periods of vegetation, is incessantly in motion, and is unquestionably analogous to the blood of animals. But the motion of the sap in plants is a great deal more complicated and altogether different from the circulation of the blood in animals. The sap is not, like the blood, confined to a separate system of vessels, for owing to the manner in which the vascular and cellular tissues are interwoven with each other, and the general permeability of all the organs, a general transfusion of the sap from cell to cell takes place endosmotically in every direction. This is particularly the case at the commencement of growth, as in germinating plantlets, or developing leaf-buds, but as soon as woody fibre and vascular tissue or ducts are formed, they take the most active part in the upward conveyance of the sap for which they are well adapted by their tubular and capillary character.

The current of ascending sap flows through the vitally active and forming cells of the alburnum or sap-wood, situated nearest the bark, and not at all through the dead wood cells of the duramen or heart-wood, situated in the interior of the stem. It is this interposed stratum of sap which renders the bark and wood so easily separable in the spring of the year.

The sap in plants appears to be set in motion by the expansion of the buds. The extremities of the branches are always more herbaceous than the part of the branches immediately below them, and therefore are the first to be affected by an increase of temperature in early spring. So soon as the extremities of the branches together with the buds begin to swell, the cells of which they are composed attract the sap from the tissues in their immediate neighborhood, which tissues are

Fig. 14.

Fig. 14. Experiment of Hales to show the force with which the sap ascends. *c.* Stock of vine cut. *t.* Tube with double curvature fastened to the top of the stock by a copper cap *v,* which is secured by a lute and piece of bladder *m.* *n n.* Level of the mercurial column in the two branches of the tube at the commencement of the experiment. *n' n'* Level at its close.

again refilled by the flow of the sap from the subjacent tissues, and in this manner the sap is gradually set in motion from the extremities of the branches to the roots through the entire system of the plant. When at length the young branches have developed themselves from the buds, and the leaves are spread abroad in the atmosphere, the ascent of the sap becomes powerfully accelerated by the evaporation which takes place from their surface.

The height to which the sap rises in forest trees is very great, and the force with which it ascends is very considerable. The force with which the sap ascends in the stem of the vine was measured by Hales, a celebrated English physician. In the early part of the month of April, he fitted a bent tube to one extremity of the stem of a grape-vine, which he had cut down to about two and a half feet above the ground. This tube was graduated and its curve filled with mercury. In a few days he found that the ascending force of the sap had raised the mercury upwards of 38 inches. Now, since the pressure of the atmosphere supports a column of mercury varying from 28 to 30 inches in height, it follows that the ascending force of the sap is greater than the pressure of the atmosphere. In some of his experiments, Hales calculated that the ascending force of the sap in the stem of the vine was five times greater than that which impels the blood through the principal artery of the horse. A piece of bladder tied over the stump of another vine, from which a piece had been cut off early in May, was torn into shreds by the rising of the sap.

As the sap rising in the stem attains a greater distance from the root, it becomes less watery and more thick and mucilaginous. It finds, in effect, amassed in the tissues which it traverses, portions of gum, sugar, starch, &c., left in them by the

growth of the previous year, which it re-dissolves and carries along with it; so that the sap which circulates in the superior parts of a plant offers a composition more rich in organic principles.

It is, however, principally in the leaves that the sap undergoes those changes which render it subservient to the growth and nutrition of the plant. In the leaves, the sap is exposed to the influences of the light and air, and is thickened and condensed by the evaporation of the useless water. Under the influence of light, the oxygen of the carbonic acid is given off from the leaves into the atmosphere, and the carbon is fixed, chlorophyl being formed in the cells. The sap is distributed to all parts of the leaf by means of the veins in the leaf, which are immediately connected with the alburnum or sapwood of the stem. The mechanism of the leaf and the action of the pores has been already explained. Not only the leaves, but the young branches, scales, and all the herbaceous or green parts of the plant, act on the atmosphere in a similar manner to the leaves.

After having been elaborated in the leaves, the sap, which is now called the *proper juice*, re-descends from the leaves towards the root.

The vascular and cellular system of the leaf not only offers the same composition as the stem, but it preserves the same relative situation in the leaf as in the stem; those vessels which occupied the interior of the stem next to the pith, becoming superior in the leaf whilst the more external vessels become inferior, and all retaining the same relative parallelism in the petiole and lamina.

Now the fibro-vascular tissue which thus issues from the stem into the petiole, consists of two layers of vessels, an

Fig. 15.

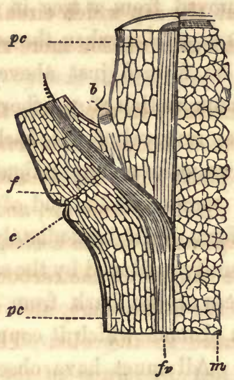


Fig 15. Vertical section through a young branch and petiole, showing the manner in which the vascular and cellular tissues of the leaf communicate with those of the stem. *m* pith of the stem; *fv* fibro-vascular tissue next the pith passing into the petiole which is articulated to the axis; *pc*, *pc* parenchyma of the stem; *b*, bud in the axil of the leaf; *c*, cushion or swelling below the leaf; *f*, forming fracture.

ex-current layer situated on the upper surface of the petiole and lamina, and which is immediately connected with the alburnum of the stem, and a recurrent layer situated immediately beneath the first layer, on the under surface of the petiole and lamina, which is connected with the endophleum or inner fibrous bark. The sap is brought from the alburnum by the ex-current or upper-layer, into the leaf and distributed to all parts of its upper surface; having undergone all those chemical changes which render it suitable for vegetable assimilation, or having been elaborated into proper juice, then conveyed by the recurrent layer of fibres along the under surface of the lamina and petiole into the bark, down which it descends to the roots.

That the sap re-descends from the leaves to the roots by the

bark is evident from the following simple experiment. If a ring of bark be removed from a tree in spring, the sap will rise just the same as usual, but when the sap begins to descend, a protuberance will be formed just above the ring, which is occasioned by the accumulation of sap there, its farther descent being stopped by the removal of the bark. The same effect will be produced if we make a simple ligature or annular compression of a young stem. At the end of a year or two a circular swelling will form itself immediately above the ligature. This swelling is evidently produced by the sap, which descending through the thickness of the bark from the summit of the stem, and finding an obstacle which it cannot pass, accumulates above that obstacle. All must have observed the distortions which twining stems thus produce on the trunks of the trees about which they entwine themselves.

So also we see the reason why the branch of a fruit tree, when sterile, may be made to flower and fruit abundantly by being girdled. This consists in removing a narrow ring of bark from the branch, sufficient to arrest the downward course of the elaborated sap, which is thus accumulated in the branch sufficient in quantity to produce this desirable result.

The ascending and descending sap are very different both in appearance and qualities. The ascending sap in all plants is nearly the same, containing no noxious qualities even in the most poisonous. We are told, by Berthellot, that the natives of the Canary Islands tear off the bark from the poisonous Euphorbia Canarensis, and find the ascending sap which they obtain from the alburnum a refreshing drink, whilst the descending sap is of so acrid a nature that it acts as a caustic, burning the flesh off such as happen to touch it. In the maple, and some other plants, the ascending sap is so sweet that sugar

may be obtained from it by evaporation, whilst the descending sap of the same tree does not possess any sweetness.

Besides this general circulation of the sap through the entire cellular and vascular system of the plant, an independent circulation or movement of rotation has been observed in the cells themselves, considered separately and individually. This is well seen in those cells which form the hairs of plants which are conveniently situated for observation. The string of bead-like cells which compose the jointed hairs of the Tradescantia Virginica, or the spiderwort, show this circulation distinctly under a magnifying power of about 400 diameters. In the tubular cells of Chara, an aquatic plant growing in stagnant pools, this circulation may be seen with an ordinary microscope. The motion of the currents in the cells of these plants is rendered visible by the minute grains of chlorophyl which they carry along with them. The cause of these motions is at present wholly unknown.

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ORGANS OF REPRODUCTION

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CHAPTER VIII.

GENERAL CONSIDERATIONS ON THE FLOWER.

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Now precisely the same is the principle and plan of structure in the vegetable world. The essential organs of plants consist of the root, stem and leaves; no new organ is introduced, but these common elements of vegetable structure are developed in peculiar and appropriate forms to suit the several wants of the plants.

When we look at a plant in full bloom we are apt to regard it as an organized being of a very complex character, and to look on the green leaves of its stem, and the several members

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ALL intelligent naturalists are agreed that a similar principle and plan of structure pervades the whole chain of animal organization, and that the same organs are developed under different forms to meet the peculiar wants and self-preservative instincts of the animal. Thus, the arm of man, the foreleg of quadrupeds, the true wing of birds, and even the pectoral fin of fishes, all represent one and the same organ developed under widely different forms, in accordance with those purposes to which they are subservient in the animal economy.

Now precisely the same is the principle and plan of structure in the vegetable world. The essential organs of plants consist of the root, stem and leaves; no new organ is introduced, but these common elements of vegetable structure are developed in peculiar and appropriate forms to suit the several wants of the plant.

When we look at a plant in full bloom, we are apt to regard it as an organized being of a very complex character, and to look on the green leaves of its stem, and the several members

or component parts of its flower, as entirely distinct in their derivation and character. A more extensive acquaintance with floral structure soon, however, discloses the interesting and important fact, that all the beautiful and highly organized parts of the flower are only a series of progressively metamorphosed leaves; which have assumed these lovely colors and this peculiar arrangement and form, in consequence of the peculiar functions assigned them.

The green leaves on the stem and branches are concerned in the functions of nutrition; they decompose carbonic acid gas, and, under the influence of solar light, chlorophyl is formed in their cells, (χλωϱός green, and φύλλον a leaf,) so called because it is the substance which gives to the leaves their green hues. The leaves of the stem take their peculiar color and form in consequence of their action on the atmosphere; they take in food from the air, which, in connection with that absorbed by the roots from the soil, contributes directly to the growth or the extension of the parts of the plant.

The leaves which constitute the flower, on the other hand, are concerned in the functions of reproduction, and are therefore modified in their structure, form, arrangement, and color, so that they are beautifully adapted to the exercise of these functions. The organs of reproduction which are collectively designated as the flower, are therefore only a peculiar modification of the organs of nutrition. A flower-bud only differs from a leaf-bud in having no power of extension. Like the leaf-bud, it is a shortened branch, the axis of which has not been elongated, and however the parts of the flower may differ from the ordinary leaves of the plant in appearance, we shall presently show that they may all be referred to the leaf as a type, their nature being precisely the same, and appearance dissimilar in consequence of a difference in the functions assigned them.

Hence when the student has acquired a knowledge of the anatomy and functions of leaves, he is prepared to enter on the consideration of the floral organs.

It has been shown that every plant which consists of more than one cell, or of a series of cells united together, may be divided into two distinct parts, to which separate functions are assigned, a vegetative part and a reproductive part. In the more highly organized plants, the vegetative part of the plant consists of the root, the stem, and the leaves, each having distinct functions assigned in the vegetable economy. Now every plant continues to grow so long as its vegetative cells continue to develop; but when the plant acquires all its developments, or arrives at an adult state, the reproductive cells show themselves, and growth stops in that direction: the whole force of vegetation being expended in the production of the spore or seed, the embryo or germ of the future plant.

In the more highly organized plants, the cells which are connected with reproduction make their appearance in the form of beautiful whorls of metamorphosed and colored leaves, constituting that part of the plant which is popularly called the flower; and we are about to trace those curious processes which are carried on by them, or their physiological action in the production of the embryo or seed, which contains within itself the rudiments of future generations.

That flowering is an exhaustive process and therefore necessarily causes the cessation of the growth or extension of the parts of plants, is evident from the following facts. Plants will continue to grow if the flower buds are removed as soon as they are formed. This is often done by gardeners, who nip off the young flower buds in order to encourage the growth of the plant, which is thus enabled to accumulate a greater store

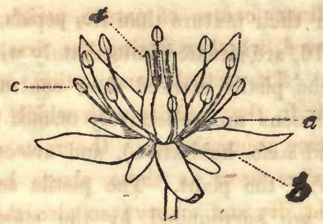
of nutriment, and finally to produce finer flowers and fruit. By removing their flower buds as soon as formed and thus preventing the exhaustion consequent on flowering, annuals may be changed into biennials, or even perennials, their life being prolonged indefinitely; whilst the same plants left to flower in the ordinary course of nature, perish as soon as they flower and bear seed, whether during the first, second, or any succeeding year. The actual consumption of nutriment in flowering, is seen in the rapidity with which the farinaceous and saccharine store accumulated in the roots of the beet and carrot disappears as soon as these plants begin to flower, leaving them light, dry and empty; so also the esculent roots of radishes and turnips become fibrous and unfit for food, when they are allowed to run to seed. When the branch of a fruit tree is sterile, it may be made to flower and fruit abundantly by being girdled. This consists in the removal of a narrow ring of bark from the branch, sufficient to arrest the downward course of the elaborated sap, which is thus accumulated in the branch in a sufficient quantity to produce this desirable result.

The reproductive organs show themselves only at the epoch when the plant acquires all its development, or arrives at an adult state. The period when this event occurs depends on the peculiar organization of the plant. At this time a change takes place in the primary mode of development, the buds in the axils of the leaves or at the extremities of the branches cease to elongate, and the internodes or naked intervals of stem between the leaves being non-developed, the leaves remain crowded together in whorls, in a sort of rosette, and undergoing peculiar modifications in their form and color, a flower is produced.

Every flower, when complete, consists of four whorls of pro-

gressively metamorphosed leaves, called respectively the calyx, the corolla, the stamens, and pistils. Of these four verticils, the two outer whorls marked *a* and *b*, in Fig. 16, are called

Fig. 16.



floral envelopes, and are considered to be merely accessary organs, whose functions are to protect the two inner whorls, the stamens and pistils marked *c* and *d*, which are named sexual organs, and which are by far the most important and highly organized parts of the flower. A flower may be perfect and reproduce itself without either calyx or corolla, but not without stamens or pistils; for these last organs are immediately connected with the formation of the seed, the germ of the future plant, and without these secreting and all-important bodies, it is impossible for fertilization to take place, or seed to be produced.

The leaves of the flower, like those of the stem, are arranged spirally about the axis of growth, and therefore the separate pieces of each verticil alternate with each other. Thus the petals or leaves of the corolla alternate with the sepals or leaves of the calyx; that is to say, each petal is placed in the interval between two sepals; the stamens alternate with the petals and the pistils with the stamens.

The sepals of the calyx, or outermost of the floral whorls,

are usually colored green, and are the nearest allied to the leaves of the stem, both in form and appearance; the petals of the corolla, or innermost floral envelope, are usually of some other color than green, as for instance, white, red, blue, yellow, or some intermediate shade of these colors, and more delicate and beautiful in their texture than the sepals. The stamens marked *c* in fig. 16, are situated immediately within the corolla, and surround the pistils marked *d*, or central organs of the flower. The stamens are collectively termed the andrœcium (ἀνὴρ a male, and οἰκίον habitation), and are considered to be the male organs of the plant. The pistils occupy the centre of the flower, are surrounded by the stamens and floral envelopes, and after flowering are changed into fruit, and contain the seed. The pistils are collectively termed the gymnœcium (γυνὴ a female, and οἰκίον a habitation), and are considered to be the female organs of the plant.

All these organs of the flower are situated on the summit of the peduncle or flower-stalk, and the part on which they are situated has received the name of thalamus, torus, or receptacle.

The different organs of the flower are verticillate leaves brought into close proximity, in consequence of the non-development of the floral internodes. This fact is beautifully confirmed by the appearance of an internode, or naked portion of stem, in some species between one or more of the floral whorls, by which they become separated from each other, just as the whorls of leaves are separated on the stem. Thus the internode, or naked interval of stem between the stamens and pistils is developed in Euphorbia corollata, flowering spurge (Fig. 17), the pistil *a* being elevated, after it is fertilized, on a little stalk, and thus lifted, as it were, from out of the midst of the

stamens and floral envelopes; so also in the genus Gynandropsis (Fig. 18), which belongs to the caper family, the stami-

Fig. 18.

Fig. 17.

nate leaves marked *s* are separated from those of the corolla *c*, by the development of the internode or naked interval of stem between them; and the pistil *p* is also separated from the stamens by the development of another internode, and supported, as it were, on a little stalk or pedicel. Usually, however, the floral internodes remain undeveloped, and therefore such appearances of the whorls may be justly regarded as an abnormal condition of things. Aberrant forms and monstrosities, whether in the vegetable or in the animal world, are always exceedingly instructive, and furnish rich materials towards cultivating and expanding our knowledge of the regularly developing organism.

CHAPTER IX.

THE INFLORESCENCE.

The arrangement of flowers on the stem or floral axis is called the inflorescence. Flower buds, like leaf buds, are either terminal or lateral. Flowers are terminal when the bud which terminates the axis of growth is a flower-bud. This of course stops the farther growth of the plant in that direction. Flowers are lateral when the bud which terminates the axis of growth develops as a leaf-bud. In this case the floral axis goes on extending itself indefinitely, and the flowers spring from the sides of the axis of growth, as shown in Fig. 19, from the axilla marked *b*.

Fig. 19.

The Bracts, or floral leaves. These bracts are situated all along the floral axis at the basis of the peduncle or flower-stalk, and are simply the ordinary leaves of the stem reduced in size in consequence of the absorption of nutriment from them by the flower. These bracts become smaller in propor-

tion as they approach the upper part of the floral axis. Hence the leaf gradually passes into the bract in consequence of its development in the neighborhood of the flower, and the same proximity doubtless produces the abortive leaves of the calyx.

Sometimes, however, the bracts are as richly colored as the petals themselves, as in Castilleja euchroma, or the painted cup, which owes all its beauty to its conspicuous and deep scarlet bracts. The curious envelope of the Indian turnip, (Arum triphyllum), and the Ethiopian lily, (Calla Ethiopica), called a spathe, is nothing but a colored bract; so also the conspicuous petal-like involucre or bract of the dogwood, (Cornus florida), is much more showy than the real flowers which it surrounds.

Bracts are generally distinct from each other; but when the flowers are brought together and situated on a common receptacle as in Umbelliferous and Composite plants, the bracts are also brought together and surround the basis of the general receptacle in one or more verticils or whorls. In the Umbelliferæ, there is usually a whorl of bracts surrounding the general umbel, which is called an involucre, and in some genera another whorl of bracts also surrounds the umbellets, termed an involucel. In the Compositæ, the involucre consists of several rows of imbricated bracts which surround the head of flowers, as in the Aster, the Solidago and the Helianthemum. Not unfrequently the separate flowers also are subtended by bracts, termed paleæ or chaff. In the grasses, bracts occupy the place of both calyx and corolla. They form the cupula or cup of the acorn, and also the husky covering of the hazel-nut.

The leaf appears to pass by means of the bract into the sepal or calyx leaf. There is in reality no exact limits between common leaves and bracts, and the limits between bracts and

sepals are equally imperceptible, such is the gradual transition of one into the other. The gradual transition of the bract into the sepal is well seen in composite flowers such as the marigold, the involucre or calyx of which is composed of numerous bracts and sepals more or less soldered together. The same transition is also visible in the common hollyhock of the gardens, the leaves of which approximate together, become modified in size and appearance, and slide as it were insensibly into a calyx.

As flower buds are produced in the axils of bracts, and as bracts are only modified leaves, it follows that the arrangement of flower buds follows the same law as the arrangement of leaf buds, the flower bud being merely the last term of ramification.

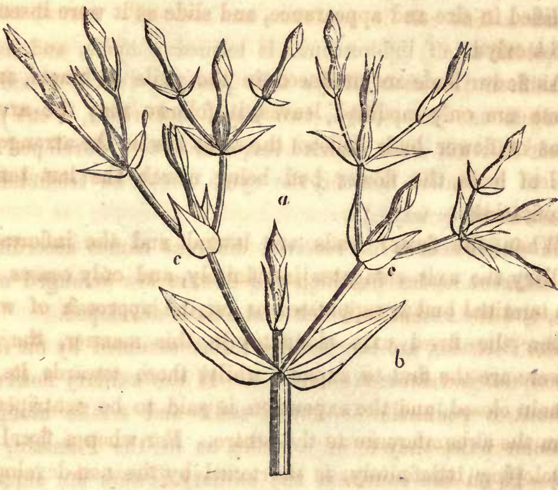
When the flower buds are lateral and the inflorescence axillary the axis elongates indefinitely, and only ceases when the terminal bud is suppressed or on the approach of winter. When the floral axis elongates in this manner, the lower flowers are the first to expand, whilst those towards its apex remain closed, and the expansion is said to be centripetal or from the circumference to the centre. For when a floral axis, developing indefinitely, is shortened by the non-development of the floral internodes, so that the flowers are brought together in clusters at its summit; the outermost flowers, which correspond to the lowest flowers of the lengthened axis, will be the first to expand, whilst the innermost flowers, which answer to those at its apex, will remain closed. The expansion of the flowers will be therefore necessarily centripetal, or from the circumference to the centre.

When the flower buds are terminal, the elongation of the floral axis is necessarily arrested; it is nevertheless able to

extend itself by secondary and tertiary axes, which are also arrested in their growth by the expanding flower at their summit.

If we take, for example, the inflorescence of Erythræa centaurium, (Fig. 20,) we shall see at the summit of the

Fig. 20.



primary axis a flower, *a*, which is truly terminal; but from either axis of the first pair of leaves or bracts at *b*, arises a secondary axis, each axis being similarly terminated by a single flower, and bearing also two pairs of bracts, *c*, *c*, which in their turn, give rise to unifloral tertiary axes, and so on.

As the secondary axis arises from leaves below the primary and central flower, the flower at the apex of the secondary axis, is consequently farther removed from the centre of growth; and the same remark applies to the flower at the

summit of the tertiary or any other succeeding axis which may be developed. In this case, therefore, since the flower terminating the growth of the primary axis is the oldest, and consequently the first to expand, the other flowers expanding in succession in proportion as they are removed farther from the centre,—the expansion of the flowers is necessarily centrifugal, or from the centre to the circumference.

This mode of inflorescence is termed a cyme, and as the divisions in this case always take place by two, it is called a dichotomous cyme, (δίχα, two ways, and τέμνω, I cut.) If, instead of two, three whorled leaves or bracts developed floral axes in a similar manner, the cyme would be trichotomous, (τρίχα, in three ways.)

The inflorescence has received different names according to the different modes in which the flowers are arranged on the axis, and the extent to which that axis is developed.

The following are the leading forms assumed by *the indefinite or indeterminate inflorescence.* If the axillary flowers are without a peduncle or flower stalk and sessile along the common axis, they form a spike, as in the Plantain, (Fig. 21.) If, on the contrary, the axillary flowers are supported on a peduncle under the same circumstances, they form a raceme, as in the wild cherry, (Fig. 22.)

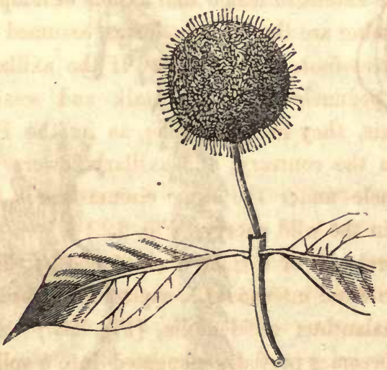
If the floral axis of a spike is shortened by the non-development of the floral internodes, a capitulum or head is produced, as in Cephalanthus occidentalis, (Fig. 23.) Sometimes the capitulum becomes partially elongated into a spike as it grows older, as in Sanguisorba and many species of Clover. The shortened axis of a head is called a receptacle.

Frequently, instead of being globular as in Cephalanthus,

Fig. 21.

Fig. 22.

Fig. 23.



or prolonged as in Clover, the apex of the floral axis is dilated horizontally, so as to allow a large number of flowers to grow

together on its flat or convex surface. What are called compound flowers, as the Helianthemum, Aster and Dandelion, are heads of this nature, surrounded by a common involucre of bracts. This flat, dilated receptacle, is very conspicuous in the Dandelion after its ripe pericarps have been removed by the wind.

If the spike be succulent and covered with unisexual flowers, ordinarily incomplete, that is to say, without floral envelopes, and if the whole be enclosed in a spathe, the inflorescence is called a spadix, as in Arum maculatum, (Fig. 24.)

If the spike be covered with unisexual flowers, male or female, borne in the axils of bracts, the axis of the spike being articulated at its base so that it is detached and falls off all in one piece, the inflorescence is termed an amentum or catkin, (Fig. 25.)

Fig. 24.

Fig. 25.

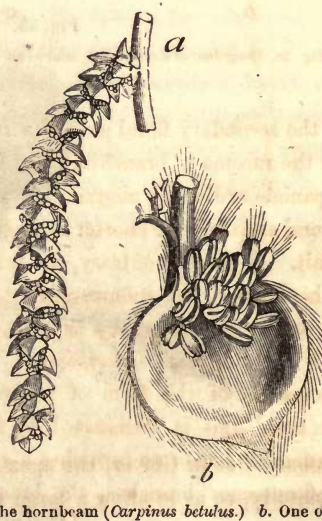
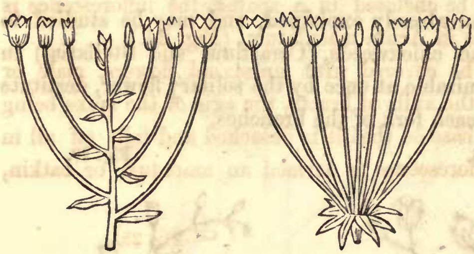


Fig. 25. *a* Unisexual amentum of the hornbeam (*Carpinus betulus.*) *b.* One of the flowers with its subtending bract magnified.

When the floral axis of a raceme is so shortened, and the peduncles of the lower flowers are so elongated, as to elevate them to the same level as the upper flowers, a corymb is formed, as in Achillea millefolium. If the floral axis of a raceme be suppressed altogether, so that the peduncles all start from the same point, we have an umbel, (Fig. 26.)

Fig. 26.



b *c*

Fig. 28. Diagrams of a corymb *b*, and of an umbel *c*.

Fig. 27.

If the secondary floral axis of a raceme gives rise to tertiary ones, the raceme is branching, and forms a panicle, (Fig. 27.) The panicle ordinarily assumes a pyramidal form, that is to say, the floral axes become shorter in proportion as they approach the summit. If on the contrary, the floral axes of the middle part are the longest, the inflorescence takes a more or less ovoid form, and is denominated a thyrsus, as in the lilac.

The definite and determinate inflorescence. The lowest developments of this form of inflorescence, is that in which a single floral axis is terminated by a solitary flower, of which the Anemone nemorosa furnishes a good example. When such an inflorescence branches, the branches do not grow in an

indeterminate manner, but are arrested in their development by the terminal flowers.

The most common and regular cases of determinate inflorescence occur in opposite-leaved plants. In these plants the inflorescence is composed of a superposed series of bifurcations of the primary axis, in the centre of each of which a terminal flower is situated. This mode of inflorescence, which is termed a cyme, has been already explained, and may be studied to advantage in the chickweeds, (Cerastium and Stellaria,) in which it is recognizable at once by the solitary flower, destitute of bracteoles, in each fork of the branches.

Fig. 28.

Fig. 29.

Sometimes only one of the two bracts on the primary and succeeding axes developes a flower, as in Arenaria stricta, (Fig. 28;) or the floral bract is suppressed altogether, so that the flower appears opposite the remaining bracts, (Fig. 29;) or both bracts are suppressed, and the flowers only are developed, as in Myosotis palustris, (Fig. 30.) When this is the case, the cyme assumes a remarkable curvature, turning round in a peculiar way so as to resemble a snail or the tail of a scorpion, and hence it is called a helicoid or scorpioid cyme; (ἕλιξ, a spiral, and εἶδος, form.) This form of inflorescence may be

Fig. 30.

observed in the Heliotropium Peruvianum, in the Sedums, in the Droseras or sundews, and in most Boraginaceous plants. The theoretical formation of this inflorescence may be ascertained by consulting the ideal figure placed here by the side of the scorpioid cyme of Myosotis palustris.

The first flower is situated at *b*, and terminates the growth of the primary axis *a*, *b*; from the axil of the bract, or in the place where it is suppressed at *c*, arises a secondary axis, *c*, *d*, which by its vigorous development, usurps the place of the primary axis, which is thus cast to one side. In like manner, a tertiary axis, *e*, *f*, springs from the axis *c*, *d*, at *e*, the terminal flower at *d* becoming apparently lateral, as before; in this manner a succession of unifloral axes are produced from

each other, which have the appearance of a continuous primary axis; but the flowers which appear lateral are in reality all terminal.

As might be expected, all these forms of inflorescence pass into each through endless intermediate gradations. In nature they are not so absolutely fixed as in our written definitions, and whether this or that name should be used in a particular case, is often a matter of fancy.

The manner in which the leaves of the flower are arranged in the bud, before the expansion of the flower, is called their æstivation, (*æstivus* belonging to summer,) or præfloration, (*præ*, before, and *flos*, flower.) These terms bear the same relation to the flower bud that vernation does to the leaf bud; and indeed, since the flower bud is only a modified leaf bud, as might be expected, the corresponding terms applied to vernation are used in reference to præfloration or æstivation. A few new terms are however added, descriptive of certain peculiar modifications in the general forms described in vernation.

Fig. 31.

Fig. 32.

Fig. 32. The flower bud of Althæa rosea, showing the valves of the calyx, *c*, opened, and the contorted præfloration of the petals of the corolla, *p*.

The following are the principal forms of æstivation to which the others are generally reducible.

1. The *valvate.* When the sepals or petals fit by their edges, without overlapping each other, as in the mallow.

2. The *imbricated.* When the petals or sepals cover each other by a part of their height merely, like the tiles of a roof. The calyx of the Camelia japonica, (Fig. 31,) is a good illustration of the imbricated præfloration.

3. The *contorted.* When the petals or sepals exhibit a tortion of their axis, and overlap each other's margins, the whole appearing to be more or less spirally twisted, as in the flowers of the Althæa rosea, (Fig. 31.)

CHAPTER X.

THE FLORAL ENVELOPES.

In a complete flower we find, without the stamens and pistils, two whorls of progressively metamorphosed leaves, the calyx, which is the exterior whorl, and the corolla placed immediately within the calyx. The modified leaves of the flower are brought into close proximity by the non-development of the floral internodes, in order that the several whorls may the more readily communicate with each other; which immediate communication is necessary to the production of the seed. Let us now examine more particularly the two outermost whorls of floral leaves, designated as the calyx and corolla.

The calyx, so named from *καλυξ* a cup. This forms the outermost whorl of the floral leaves, and consists in its usual state of a leafy green cup more or less divided. The sepals or leaves of the calyx differ but slightly in structure and appearance from the ordinary leaves of the stem; they are for the

most part of a greenish hue, chlorophyl being formed in their cells, and stomata or pores existing on their lower epidermis; and in some cases of monstrosity, they are actually converted into the ordinary leaves of the plant. In proliferous states of the rose, the calyx assumes a leafy aspect; whilst in Gentiana campestris and Gentiana crinita, it differs in no respect from the ordinary leaves of the plant.

The sepals of the calyx are sometimes separate from each other as in the buttercup, at other times they are united to a greater or less extent, as in the Polyanthus. When the sepals are separate from each other, whatever may be their number the calyx is polysepalous (πολυς many, *sepala* leaves;) but the term, as currently understood amongst botanists, is simply used to express the absence of cohesion amongst them, and is equivalent in meaning, to the expression sepals distinct. When the sepals of the calyx are united to each other by their margins in a greater or less degree, the calyx is monosepalous (μονος one, *sepala* leaf.) The same remarks apply to the petals of the corolla, which are polypetalous or monopetalous, according as the petals are separate from each or in a state of cohesion.

It is well known that the parts of plants which grow closely together are apt to cohere, the parts anastomosing with each other. Accidental unions of this kind among the leaves of plants are of frequent occurrence. Now owing to the non-development of the floral internodes, the metamorphosed leaves which constitute the flower are necessarily brought into closer contact, and hence they are more frequently found united with each other than the leaves of the stem.

The sepals of a monosepalous calyx may cohere together by their bases, or by their margins, through their inferior half, or through their entire length, and various terms are employed to express these different degrees of cohesion.

Fig. 33.

Fig. 33. Thus when the sepals are coherent by their bases as in the Pimpernel *a*, we employ the terms bi-partite, tri-partite, quadri-partite, according as there are two, three, or four sepals thus united. When the union of the sepals takes place through the lower half of their margins, such sepals are bi-fid, tri-fid, quadri-fid, as in Erythræa, *b*. If the sepals are united with each other by their margins nearly to their summit, they are bi-dentate, tri-dentate, as in Lychnis, *c*. Finally, if the union of the margins is complete through their entire length, the calyx is said to be entire. It is seldom, however, that the cohesion of the calycine leaves is complete, and the number of lobes at the summit of the calyx will in general show the number of sepals which have cohered together. In the entire monosepalous calyx, the venation assists in determining the number of cohering sepals.

When the sepals are unequally developed and united, the calyx is said to be irregular. This takes place in the Labiatæ, or mint tribe, where some of the sepals of the calyx unite to a greater extent than others, thus forming a bi-labiate or two-lipped calyx, as in the dead nettle, Lamium. (Fig. 34.) The upper lip is composed of three sepals, the lower of two; the united parts form the tube; the free portions the lobes or segments of the limb; and the part where they join one another the mouth or throat.

Fig. 34.

Fig. 35.

The monopetalous corolla, has corresponding terms applied to its modifications and to the degrees of cohesion amongst its petals.

When the calyx falls as soon as the corolla expands it is termed caducous, as in Sanguinaria Canadensis, which is at first enclosed in a calyx of two leaves, which fall off as soon as the flower is fully blown. The calyx is deciduous when it drops off with the corolla, but in many cases, the calyx remains after the corolla and other floral whorls have faded and fallen, as a protecting envelope to the fruit, as in the mallow, (Fig. 35.) In this case it is said to be persistent (*per* through, and *sisto* to remain.)

Sometimes the calyx and fruit cohere together, so that the calyx appears to arise from the summit of the fruit, as in the rose; such a calyx is called a superior calyx; if, on the contrary, the calyx and fruit do not cohere together, the calyx is said to be inferior, as in the strawberry. In some plants the calyx is suppressed altogether, or it may be present and reduced to a mere rim or border, as in the Umbelliferæ; or to a pappus, as in Compositæ.

A great many plants, however, have only one floral envelope exterior to the stamens and pistils, as for example, the hyacinth and the lily. The early botanists differed amongst themselves as to the term by which this single floral envelope ought to be distinguished from the others. Tournefort and Linnæus called it the *calyx* when it was green and bore the general character

of a calyx, and gave it the general name of *corolla* when by its color and the delicacy of its tissue it approximated to that organ. But this distinction is utterly worthless, for the same organ may vary in color without changing its nature. Thus, in the Fuchsia or lady's ear drop, and in Salvia splendens, one of the Mexican sages, the calyx is of the same bright scarlet color as the corolla; and in the white water-lily and magnolia, the sepals gradually approximate in color to the petals. Hence it is now agreed amongst botanists when a flower has but one envelope to its stamens and pistils, to consider it as a calyx, whatever may be its color and form.

The corolla, from "corolla" a garland, is that part of the flower situated immediately within the calyx, between the calyx and stamens. It is generally the most showy and beautifully colored of all the floral organs, and is the part which is popularly called the flower. Thus the red leaves of the rose, the yellow leaves of the buttercup, constitute the corolla of these plants.

The divisions of the corolla are called petals from (*πεταλον* a leaf.) If these petals are united by their margins so as to form apparently one petal, as in the primrose and Campanula the corolla is termed monopetalous; if, on the contrary, the petals do not cohere together, but grow separately and distinctly apart as in the rose, the corolla is said to be polypetalous. When the various divisions or petals of the corolla are alike and its incisions uniform, the corolla is regular; if otherwise, it is irregular. The lower part of a monopetalous corolla is called the tube, the upper and expanded portion the limb, and the part where the two are connected with each other the throat.

The sepals of the polysepalous calyx are usually sessile leaves, having nothing analogous to a leaf stalk at their base; but it is otherwise with the petals of the polypetalous corolla.

These, although sometimes sessile, as in the rose and crowfoot, have not unfrequently their base tapering into a narrow stalk analogous to the petiole of the leaf, which is called an unguis or claw; whilst their upper portion, which corresponds to the blade of the leaf, is broader and more expanded, and is called the lamina, as in the wall-flower. (Fig. 36.) Petals organized in this manner are termed unguiculate.

Fig. 36.

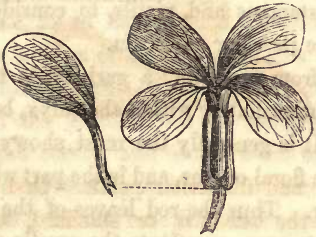


Fig. 36. Cruciform corolla and unguiculate petal of the wall-flower. (Cheiranthus.)

The following are some of the leading forms assumed by the regular polypetalous corollas. The *rosaceous*, of which the rose is the type, have spreading petals without claws or with very short ones. The *cruciform*, in which there are four petals, usually with claws, arranged in the form of a cross, as in the wall-flower. The *liliaceous*, in which the petals, six in number, gradually taper from the base to the apex, as in the lily. The *caryophyllaceous*, where the petals have long, narrow, tapering claws, which are enclosed in a tubular calyx, as in the pink.

Irregularities in the form of polypetalous corollas may result from the unequal development of the petals, as in the violet; but these are not sufficiently marked as to justify the application of any particular term. There is, however, one form

of irregularity amongst polypetalous corollas which usually receives a special notice, on account of the remarkably anomalous development of its petals, and because it is characteristic of an extensive natural order of plants, viz: the *papilionaceous* corolla, from (*papilio*, a butterfly,) of which the pea-flower furnishes a good example. (Fig. 37.) This corolla is composed

Fig. 37.

of five unequal and dissimilar petals. One larger than the rest, *a*, called the *vexillum* or standard, which is usually folded over the other petals in æstivation; two lateral petals, *b*, which are designated as the *alæ* or wings; and two inferior petals, usually completely covered by the alæ, and their lower margins so united as to form a single keel-like piece, called the *carina* or keel, *c*. This last piece embraces the essential organs, the stamens and pistils.

The following leading forms may be distinguished amongst the regular monopetalous corollas. The *campanulate*, or bell-shaped, as in Campanula rotundifolia, (Fig. 38, *a*,) which is without a tube, and which enlarges gradually from the base to the apex. The *infundibuliform* or funnel-shaped, as in the Convolvulus purpureus, or morning-glory, in which the tube is narrow below but widely-expanded towards the summit. The *hypocrateriform* or salver-shaped, as in the Phlox (Fig. 38, *b*,) where the limb spreads out at right-angles with the

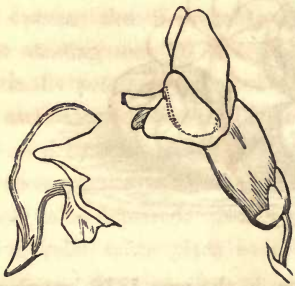
Fig. 38.

a *b*

more or less elongated tube of the corolla. The *rotate* or wheel-shaped, as in the Myosotis palustris or forget-me-not, which is a salver-shaped corolla without a tube, or with a very short one. The tubular or tube-shaped, as in the Caprifolium or honey-suckle, where the limb is not developed and the corolla is cylindrical or tubular throughout its entire length. The *urceolate* or urn-shaped, as in Vaccinium macrocarpon, the American cranberry, in which there is scarcely any limb, and the tube is narrowed at both ends and expanded in the middle.

Irregularities in the form of monopetalous corollas are produced by differences in the degrees of cohesion amongst the petals. The principal forms of irregular monopetalous corollas are :—the *labiate* or lipped, (from *labium*, a lip,) (Fig. 39, *a*,) in which the tube is more or less elongated, the throat open and dilated, and the limb divided traversely in such a way as to produce an upper and lower portion called the labia or lips, with a hiatus or gap between them, like the mouth of an animal. The upper lip is usually composed of two petals, as the

Fig. 39.



a *b*

Fig. 40.

c *d*

little notch at its summit proves; the lower, of three. When the two lips are thus gaping and the throat open, the corolla is said to be ringent, as in Lamium amplexicaule; but when the mouth is closed by the approximation of the two lips, by an elevated protuberance of the lower called the palate, as in the snap-dragon or toad-flax *b*, the corolla is designated as *personate* or masked. When a tubular corolla is split down on one side in such a way as to form a strap-shaped process with several tooth-like projections at its apex, it becomes *ligulate* (*ligula*, a little tongue,) or strap-shaped. (Fig. 40, *d.*) This kind of corolla is well seen in composite flowers such as the dandelion, in which all the flowers forming the head are ligulate. In the Compositæ there are often two kinds of florets associated in the same head. Thus the outer florets which form the white ray of the Ox-eye daisy (Leucanthemum) are ligulate, whilst those which form the yellow disk are tubular. (*c.*)

The largest flower in the world is the Rafflesia Arnoldii, (Fig. 41,) which was discovered by Sir Thomas Stamford

Fig. 41.

Raffles in the forests of Sumatra, in the year 1818, growing on the stems of the Cissus augustifolia, a kind of climbing plant or grape-vine. In the bud state this flower is nearly a foot in diameter, and when fully expanded, nine feet in circumference and three feet over from the tip of one petal to that of another. Its substance is about half an inch thick, and the whole plant weighs fifteen pounds. Its color is light orange mottled with yellowish-white, and like other parasites, it derives its nutriment from the tree on which it is found. A few other species of less gigantic size have been discovered in the other islands of the Eastern archipelago.

Structurally, the petals or leaves of the corolla are composed of cellular and vascular tissue, the latter consisting of spiral vessels and delicate tubes. The color of the petals is produced by the refined and splendidly colored juices elaborated from the sap by the walls of the cells which form their tissue or substance. This fact is easily verified by submitting to microscopic examination a fragment of the petal of a rose or of a camellia, when it will be seen that the color does not exist in the walls of the cells of the petal, but it is the result of the colored fluids with which the cells are filled.

Sometimes, by the mere juxtaposition of the different cells in the petals, a mechanical admixture of their various contents takes place; thus is probably produced that delicate and inimitable shading seen in the petals of some flowers; at other times, the petals are spotted and variegated, as in the tiger lily and balsam. Such spots result from the peculiar power, possessed by some of the cells, of attracting from the colorless sap these particular colors, and of which power the other cells appear to be deprived. No admixture of color with the neighboring cells takes place in this case. "In the petals of Impatiens balsamina, the garden balsam," says Dr. Lindley, "a single cell is frequently red in the midst of others that are colorless. Examine the red bladder, and you will find it filled with a coloring matter of which the rest are destitute."

Every one must have noticed the regularity with which these spots are formed in the petals of certain flowers, which are in fact never without them. Such cells appear to have definite functions assigned them, the exercise of which is probably as important to the healthy vital action of the plant as that of the most elaborate organs.

The chromule, or coloring substance of plants, is by no means confined to their petals, but sometimes pervades the sepals of the calyx, as we have already shown, and is even occasionally extended into the tissue of the bracts and ordinary leaves of the stem. The beautiful wild flower called Castilleja euchroma, or the painted cup, owes all its beauty to its conspicuous and deep scarlet bracts; and in Croton pictum, a plant which may be frequently met with in conservatories, the chromule tints the ordinary leaves of the plant. The analogy of the petals to the leaf is thus clearly traceable; and how-

ever dissimilar the petals of the corolla may appear to the ordinary leaves on the stem of some plants, so that we may feel disposed to regard them as separate organs, yet the evidence afforded by these transition forms shows the intimate connection subsisting between the petal, the sepal, and the bract, and the common origin of the whole of them from the ordinary stem-leaf, of which they are but modifications.

Functions of the Floral Envelopes.—The calyx and corolla are by far the most conspicuous and showy parts of the flower, and are the parts of it which usually attract popular notice. Yet their functions are entirely of a secondary and subordinate character. The internodes between the several whorls of floral leaves are not developed, in order that they may the more readily act on each other. The calyx and corolla doubtless foster and protect the two inner whorls of leaves, viz.: the stamens and pistils, which are more immediately connected with the process of reproduction than they are.

All must have noticed the folding up of the calyx and corolla at sunset, or in wet weather. The function exercised by the two outer whorls of the floral leaves is in this case clearly protective, and the design of their close proximity to the stamens is at once apparent; that they may fold over the stamens and pistils, and thus ward off the injurious effect of the night dews and falling rain, which would act injuriously on the pollen contained in the cells of the anther. Thus safely and beautifully sheltered at every epoch of their development, the stamens and pistils perform their respective functions.

The bracts and calyx, when of a green color, doubtless perform the same functions as the ordinary leaves of the stem; but it is otherwise with the petals of the corolla and with the

other parts of the flower; these exercise on the atmosphere, a different kind of influence. Before the appearance of the flowers, the plant is wholly an apparatus of reduction, all its parts being concerned in the assimilation of the food. It decomposes the carbonic acid borrowed from the atmosphere and the soil, fixing the carbon and exhaling the oxygen, and forming within its green leaves, young shoots, and superficial parts, the substance called chlorophyl. But when the flowers develope, this part of the plant becomes an apparatus of combustion. The starch granules which in the leaves were changed into chlorophyl, in the petals are changed into chromule, and become wholly oxidized and converted into saccharine matter. The carbon or sugar accumulated by the nutritive organs of the plant, is consumed by its reproductive organs. Hence we see these matters disappear at the epoch when the flowers expand, and it is therefore necessary to reap those vegetables, which we cultivate for the sugar which they contain, before that period. This disappearance of the saccharine store is the result of its slow combustion, or the conversion of the carbon of the sugar into carbonic acid. Oxygen is therefore necessarily consumed and heat evolved by the flowers, whilst at the same time carbonic acid rises from them into the atmosphere. Whilst, therefore, the green leaves of plants purify the air, their beautiful flowers contaminate it, although to a degree of course which is relatively insignificant.

The development of heat by flowers was first observed by Lamarck in the Arum maculatum of Europe. It was afterwards detected by Saussure, in the Bignonia, Gourd, and Tuberose. In these cases the heat was measured by a common thermometer. But since the invention of thermo-electric instru-

ments, heat can be detected in any ordinary cluster of flowers. The best plants for experiment are the Araceæ, where the heat is confined and reveberated by the hood-like inflorescence. In some of these plants the temperature rises at times to 20° and 50° Fahrenheit, above that of the surrounding air. The temperature rises from the first opening of the flowers, and reaches its maximum when they shed their pollen, at which time the heat developed is so great as to be perceived by the hand; it afterwards gradually declines until the flowers fade.

CHAPTER XI.

THE ESSENTIAL REPRODUCTIVE ORGANS.

THE ANDRŒCIUM OR STAMINAL ORGANS.

THE stamens are situated immediately within the corolla, and form the third verticil of the flower. They constitute, collectively, the andrœcium (ἀνὴρ a male, and οἰκίον habitation), or the male sexual organs of the plant.

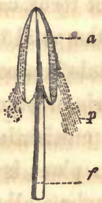
There is a power given to all plants of developing new plants out of any of their cells, when these cells are placed in suitable circumstances. In the cells of plants in general the expression of this law seldom occurs, since it is only in rare cases that the necessary conjunction of all the conditions is brought about. Nevertheless, there are cases in which the ordinary leaves of the stem may be made to develope new plants, as, for instance, the leaves of Bryophyllum calycinum which, when placed on moist earth, develope young plants from the indentations of their

margin. So, also, if a notch is made in one of the thick veins of the leaves of the splendid Gesneria, and if the leaf is placed on the ground, in about a week a new plant will be produced on its surface. The same phenomena occur in the leaves of the beautiful and scarlet-flowered Echeverias, and in many other succulent plants. Now these plants could only originate in the extraordinary development of certain cells in the leaf.

In general, however, those plants which have true leaves and flowers, have these cells always produced in their terminal leaves, which at this time take a peculiar form, as, for instance, in the stamens. These reproductive cells, which are termed pollen, are always developed in the interior of these metamorphosed leaves or stamens.

A stamen, when complete, consists of three parts; the filament, or thread-like portion, *f*; the anther, *a*, which is situated on the top of the filament, and which usually consists of two cells placed side by side, and attached to a prolongation of the filament called the connectivum or connective; and the pollen, or granular matter, *p*, contained in the cells of the anther, by means of which the ovules are impregnated, (Fig. 42.) The stamens are very conspicuous in the garden

Fig. 42.



lily, an examination of which flower will, in connection with our engraving, convey a very accurate conception of these important organs.

A fully developed leaf is composed of two parts, a little stalk or support called a petiole, and a flat expanded portion called the blade or limb, which is composed of woody fibre and parenchyma. The veins of the leaf constitute its woody fibre and form its framework or skeleton, whilst the parenchyma is the green cellular matter which fills up the interstices or intervals between the veins. Now the petiole of the leaf is represented in the stamen by the filament; the midrib by the connectivum; whilst the anther corresponds to the lamina or blade, each portion of the lamina, on either side of the connectivum or midrib, forming an anther lobe. The pollen contained in the anther-cells results from a peculiar transformation of the parenchyma or green cellular matter of the leaf.

When the stamen is destitute of a filament, the anther is said to be sessile, the filament being no more essential to the stamen than the petiole to the leaf. When the anther is imperfect, abortive, or wanting, the stamen is considered to be sterile, abortive, or rudimentary, its real nature being known by its situation.

In the stamens, the leaf undergoes such extensive structural changes that its parts can scarcely be recognized. That the stamens are only leaves which have undergone a greater metamorphosis or change of form, nature herself teaches. All will allow the analogy of the petal to the leaf. Now, the conversion of stamens into petals is a common occurrence in plants which have numerous whorls of stamens, especially when such plants are brought under cultivation, as, for example, in the rose and peony; but in no plant is it seen more clearly than in the flower of the Nymphæa alba, or white water-lily. In this flower, perfect stamens are formed in the centre, the filaments of which gradually enlarge towards the circumfe-

rence, until at length the outer whorls of stamens exactly resemble petals, except in having their tops developed into yellow anthers, as seen at *a* and *b* in (Fig. 43;) and finally the

Fig. 43.

anther disappears altogether from the summit of the petal, as at *c*, and the metamorphosis is completed.

In this manner, what are called double flowers are produced. The numerous whorls of colored petals in the rose and peony result from a metamorphosis of a part, or sometimes of the whole of their stamens into petals. This metamorphosis is the effect of cultivation, the normal number of petals in the rose being five, as is seen in the wild roses. A double flower, therefore, although an object of admiration to the gardener, is nevertheless justly regarded, scientifically, as a monstrosity.

If all the stamens are converted into petals, the flower is

necessarily sterile; but if some of the stamens are perfect, even in a double flower, there may be fruit.

The number of stamens which compose the andrœcium varies very considerably. There may be only one, as in Callitriche verna, Water star grass, or many hundreds as in the poppy. The flower, according to the number of its stamens from one to ten, is said to be monandrous (*μόνος* one, *ἀνὴρ* male,) diandrous (*δις* two,) triandrous (*τρεῖς* three,) tetrandrous (*τετρὰς* four,) pentandrous (*πέντε* five,) hexandrous (*ἕξ* six,) heptandrous (*ἑπτὰ* seven,) octandrous (*ὀκτὼ* eight,) enneandrous (*ἐννεά* nine,) decandrous (*δέκα* ten.) Above ten there is no regularity in the number of the stamens. All flowers having from twelve to twenty stamens, are designated as dodecandrous (*δώδεκα* twelve;) and if their number exceeds twenty, Polyandrous (*πολυς* many.)

Proportion of the stamens.—The relative length of the stamens is not always the same, the filaments being sometimes more or less developed in the same flower. In some cases there exists a definite relation as regards number between the long and the short stamens. When a flower encloses four stamens of which two are constantly the longest, it is called a didynamous flower, (*δὶς* twice, and *δὺναμις* power;) Fig. 44; and when there are six stamens in the same flower and four of them longer than the other two, the flower is said to be tetradynamous, (*τετρὰς* four, and *δὺναμις* power;) Fig. 45. The natural orders Labiatæ and Scrophulariaceæ furnish us with samples of the first, and Cruciferæ of the last disposition of the stamens. In the wood sorrel, (Oxalis,) there are ten stamens, monadelphous at their base, five long and five short, which alternate with each other.

Connexion of the stamens.—The stamens, in common with

Fig. 44.

Fig. 45.

the other leaves of the plant, are found in a state of cohesion in many flowers. When they cohere by their filaments to a greater or less extent, forming a tube around the pistil, as in the oxalis and mallow, (Malva,) Fig. 46, they are called mona-

Fig. 46.

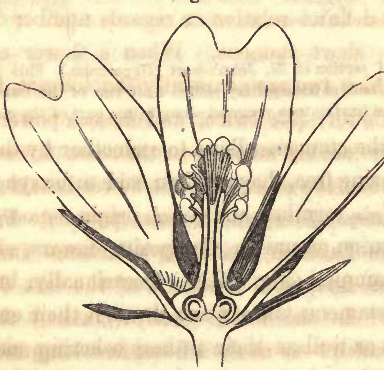


Fig. 46. Vertical section of the flower of Mallow (Malva.) The stamens are monadelphous, being united by their filaments into a cluster round the pistil.

delphous stamens (μόνος one, and ἀδελφὸς brotherhood;) diadelphous, when the filaments are united into two bundles, as in the pea and fumitory. In the latter instance, the same number of filaments cohere together in the two bundles, each of them being composed of three stamens, but in nearly all papilionaceous flowers, out of ten stamens nine are united by their filaments while one is free. When the filaments cohere into three bundles, the stamens are triadelphous, as in the St. John's-wort, (Hypericum,) Fig. 47; and when they grow together into many bundles, polyadelphous, as in Ricinus communis, the Castor oil plant, Fig. 48.

Fig. 47.

Fig. 48.

Fig. 47. Vertical section of St. John's-wort (Hypericum.) This flower has triadelphous stamens, and a tricarpellary pistil. Only two of the bundles of stamens are visible, the third having been removed along with a part of the pistil.

Sometimes the stamens adhere to each other by their anthers, the filaments being free, they are then said to be syngenesious or synantherous (σὺν together, and γενεσίς origin, or ανθηρα anthers). This kind of union occurs in Composite flowers, of which the cichory is a sample, (Fig. 49.) Occasionally, however, the union of the stamens takes place through their entire length, their filaments as well as their anthers cohering, as in Lobelia, (Fig. 50.) At length the andrœcium, instead of forming a distinct verticil about the pistil occupying the centre of the flower,

becomes united with it so as to constitute but one body. In this last case the stamens are gynandrous (γυνὴ a female, and ἀνὴρ a male), and the central body or column is called the gynostemium (γυνὴ pistil, and στημων a stamen), as in Aristolochia, (Fig. 50.)

Fig. 49.

Fig. 50.

Fig. 51.

Fig. 51. Gynandrous stamens of Aristolochia rotunda. ***a.*** **The ovary.** ***b.*** **The gymnostemium.** ***c.*** **The six stamens** ***d.*** **The six lobes of the stigma.**

Let us now examine briefly the parts of which the stamen is composed, having viewed them collectively. We have seen that a fully developed stamen is composed of a petiole termed a filament: a limb or blade named an anther, the pulverulent parenchyma contained in the anther being called pollen.

The filament or petiole of the stamen supports the anther or metamorphosed lamina of the leaf, and commonly justifies its name from its form, that is to say, it is generally filiform and slender. Sometimes, however, it is dilated and petaloid, as in Ornithogalum umbellatum, the Star of Bethlehem, a white flower with a bulbous root, quite common in meadows and pastures about the middle of Spring.

Filaments are usually of a white color, but occasionally they take the same hues as the corolla. In Tradescantia Virginica, the spiderwort, the filaments are blue; in the different varieties of the Fuchsia or lady's ear-drop, they are red, and in Ranunculus acris, yellow.

The anther is generally situated at the summit of the filament, to which it is attached in a variety of ways. Sometimes it adheres to the filament by its entire length, when it is said to be adnate, as in Magnolia glauca; or its base rests directly on the apex of the filament, when it is innate, as in Sanguisorba Canadensis, or burnet; or it may be attached by a point to the apex of the filament on which it lightly swings, when it is versatile, as in the grasses.

The anther is the most essential part of the stamen. It contains the pollen or fecundating matter, before the act of fecundation. It is most generally formed of two little pouches or cells supported against each other by one of their sides, or united together by an intermediate body, to which the name connectivum or connective has been given. In this case the anther is bilocular, (*bis*, twice, *loculus*, a pouch.) More rarely the anthers are unilocular, as in the mallow, or quadrilocular, as in Butomus umbellatus, the flowering rush; a plant occasionally met with in England in brooks and rivulets.

The pollen or fecundating matter, when artificially removed from the anther cells, looks to the naked eye like powdery matter devoid of all organization, and is usually of a yellow color; but it is also purple, blue, scarlet, black, and various other shades. Placed beneath the microscope, this powder resolves itself into a collection of spherical or oval grains, the surfaces of which are generally smooth, but sometimes furnished with strong points or bristles, as in the hollyhock,

(Althea.) In most plants these grains are free amongst themselves; but in the Fuchsia and Ænothera biennis, or evening primrose, they are held together by slender threads, and in other genera they adhere together in masses called pollinia.

Pulverulent pollen. This is its most general aspect and disposition. Pollen cells are ordinarily composed of two membranes, which are distinguished as external and internal. The interior of the cells is filled with a mucilaginous fluid matter, containing granules, named fovilla. The exterior membrane of the pollen cell, denominated the extine, (*exto*, to stand out,) is thick, firm, and is readily ruptured by distension. It is this membrane which is covered with papillæ or granulations, the surface of the pollen being rarely smooth. It is applied immediately on the internal membrane, or intine, (*intus*, within.) This membrane is thin, transparent, very extensible, and without any appreciable organization.

The mucilaginous fluid and granular matter in the interior of the pollen cells has been the object of a great deal of discussion amongst physiologists. The fovilla exhibit very marked movements in the fluid where they swim. These movements, it was at first thought were spontaneous, and the pollenic granules were supposed to be assimilated by them to the zoosperms of animals. But the analogy has been completely destroyed by an examination of the chemical nature of these bodies, which are nothing but grains of starch, turning blue with iodine, and showing all the characters of the fecula taken from the other parts of the plant. This observation is due to M. Fritsch of Berlin, who published in 1832 and 1833 two interesting dissertations on pollen.

Solid pollen is that in which the grains instead of being distinct are united together in masses, which in general take

the form of the cells of the anther which serves as a kind of mould. The name pollinia has been given to these agglomerations. It is only in the family of Orchidaceæ amongst Monocotyledons, and that of Asclepiadacæ in Dicotyledons that we observe solid pollen.

In orchideous plants each of the pollen masses is supported on a stalk called a caudicle (*cauda* a tail), which carries at its extremity a glandular body called a retinacula (*retinaculum* a band or rein), by means of which it is attached to the stigma. These masses when bruised divide into grains which are agglutinated together in fours.

Fig. 52.

Fig. 52. ***a.*** **Represents one of these pollen masses, with its caudicle.** ***b.*** **The retinacula.** ***c.*** **Some of the grains separated from a similar mass to show the nature of their agglomeration.**

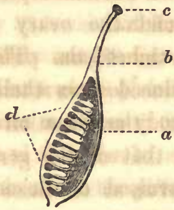
CHAPTER XII.

THE GYMNŒCIUM OR PISTILLINE ORGANS.

THE pistil occupies the centre of the flower and terminates the axis of growth. The pistils constitute collectively the Gymnœcium (γυνὴ pistil, and οἰκίον habitation,) or female sexual organs of the plant.

When fully developed the pistil, like the stamen, consists of three parts, the stigma, the style, and the ovary (Fig. 53.)

Fig. 53.



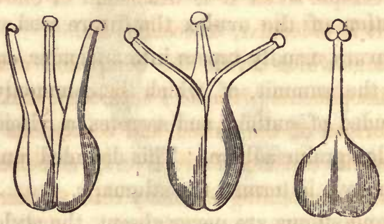
The ovary *a*, is the lower part of the pistil, containing within its cavity the ovules or rudimentary seeds *d*, and forms after the impregnation of the ovules the future seed vessel. The apex of the ovary usually tapers into a slender column called the style *b*, the summit of which is commonly somewhat enlarged, denuded of cuticle, and secretes a viscid matter to which the pollen grains adhere. This denuded and glandular summit of the style is termed the stigma, *c*.

The ovary and stigma are never absent, the style sometimes is; in which case the top of the ovary itself is called the stigma, as in the poppy, where it appears like the spokes of a wheel.

Like the other organs of the flower, the pistil is composed of one or more modified leaves, which in this instance are called carpels, from their connexion with the fruit, (καρπος, fruit.) These leaves are folded inwardly, and their margins united, so that their lower surface forms the outside, and their upper surface the inside of the carpel, the ovules being developed along the margin of the leaves. That this is the true nature of the pistil, the monstrous variety of the garden cherry conclusively proves. In this flower, the place of the pistil is

occupied by a green leaf, somewhat folded together, and similar to the leaves of the branches, except in its lesser size. If we compare this leaf, with the perfect pistil of the cherry, we shall see that the folded lamina answers to the ovary, the midrib projecting beyond the ovary to the style, and its slightly dilated apex to the stigma. The analogy of carpels to leaves may also be deduced from their similarity in texture and venation, and from the situation of the ovules, which exactly corresponds to that of the germs or buds found on the margin of some leaves, as on those of Bryophyllum calycinum.

Fig. 54.



a *b* *c*

The modified leaves or carpels forming the gymnæcium, cohere together to a greater or less extent, like the parts of the flower; and all degrees of union amongst them may be observed from the mere cohesion of the contiguous bases of their ovaries, (Fig. 54, *a*) to their perfect consolidation whilst their styles are distinct, *b*. In other species, both the ovaries and styles of the carpels are consolidated, and the whole gymnœcium forms an unique body, which may be mistaken for a single pistil, *c*. But single pistils are by no means so common as is usually supposed. If we make a transverse section of the ovary

of this apparently single pistil, we shall find a number of cells, which are in general equal to the number of consolidated carpels or pistils. If the ovary of the lily, for example, be cut in this manner, what appears at first view to be a single pistil will be found in reality to consist of three united ones.

When the carpel and pistils of the gymnœcium are all distinct the pistil is termed apocarpous, (ἀπὸ separate, and καρπος fruit,) when they are united into one mass it is said to be syncarpous, (σὺν together or united.)

Let us now carefully examine the different parts of the pistils.

The ovary is the inferior part of the carpel or pistil, and contains the ovules within its cavity. It is either simple or compound. Simple when it is unilocular or one-celled; compound when it is bi-locular, tri-locular, &c.

The partitions which divide the compound ovary into cells are termed dissepiments (*dissepio* I separate); and each dissepiment being formed of the united and contiguous walls of two carpels, necessarily consists of two layers, one belonging to each carpel, the ovary containing as many cells as there are carpels in the compound pistil.

The placenta is the line or ridge to which the ovules are attached, and corresponds to the ventral suture or line formed by the union of the margins of the carpellary leaves.

The simple pistil has of course a one-celled ovary, but not unfrequently the ovary of the compound pistil is also unilocular. For the edges of the carpellary leaves are sometimes folded inwardly, and form imperfect dissepiments which project more or less into the cavity of the ovary but do not divide it into cells. In this case the ovary is necessarily unilocular, although it may be connected with a compound pistil.

If we suppose a circle of three carpellary leaves with their

margins turned inwards, yet not so as to meet in the centre of the ovary, to cohere merely by their contiguous inflexed por-

Fig. 55.

tions, a one-celled tri-carpellary ovary would result, with three imperfect dissepiments projecting into its cavity, in Fig. 55, *a*. If we imagine the margins of three carpellary leaves to cohere, making only three slight introflexions, it is obvious that there would be no dissepiments, and the placentas would be truly parietal (*paries* a wall) the ovules being borne directly on the walls of the ovary, as at *b*. If, on the contrary, we suppose the three carpellary leaves to be so folded inwardly as to carry the inflexed portions of their united lamina, or in other words, their dissepiments to the centre, and the dissepiments there to unite and form a common axis, about which the ovules develope; and if we then imagine the walls of the dissepiments to be ruptured by the rapid growth of the ovary, it is obvious that we shall have what is called a free central placenta, as shown at *c*, Fig. 55, and also in Fig. 56. In all these cases the compound pistil has an unilocular ovary.

All gradations may be observed in nature between strictly parietal placenta and those which are carried forward so as to meet in the centre of the ovary and separate its cavity into distinct cells.

In the Dog's-tooth violet (Erythronium) and Campanula the walls of the dissepiments are not ruptured. Fig. 55 is a tra-

Fig. 55.

Fig. 56.

Fig. 56. Vertical section of the tricarpellary ovary of Spergularia rubra, a plant belonging to the chickweed family, showing the attachment of the ovules to a free central placenta.

verse section of the trilocular or three-celled ovary of the Erythronium. The ovules are attached to a central placenta. In this instance the compound character of the ovary is sufficiently evident.

In the chickweed family, Fig. 56, the dissepiments at first project across the cavity of the ovary and meet in its centre, but are finally torn asunder by the expansion of the ovary, so that the several loculi communicate, the ovules remaining attached to the placentas in the middle. The vestiges of the dissepiments remain attached to the walls of the ovary, proving that this is the mode in which free central placentations are produced. In the blood-root and violet, the placenta are strictly parietal.

In most cases the compound pistil, provided with a one-celled ovary, is easily recognized. Thus every time that an unilocular ovary is surmounted by several free styles and stigmas, or by the same united amongst themselves and only distinguishable at their summit by some slight incision, the pistil will be compound. It is only necessary to remember that a pistil is never without an ovary and stigma, and in most cases possesses a

style; the plurality of styles and stigmas therefore necessarily proves a plurality of pistils.

In general the carpels contract no adhesion with the floral envelopes. They are simply attached to the receptacle, so that when they grow and elevate themselves they remain perfectly intact. We say in this case that the ovary is free and superior, being situated above the floral envelopes, and that the stamens are perigynous (περὶ around, and γυνὴ pistil.) But sometimes the calyx grows to the surface of the ovary carrying with it the petals and stamens, so that all these organs seem to rise as it were out of the summit of the ovary, as in the honeysuckle and dog-wood. The ovary in this instance is inferior, as it is situated below the floral envelopes, and the stamens epigynous (ἐπὶ upon, γυνὴ pistil.) This distinction between the inferior and superior ovary is very important, as it serves to distinguish certain natural families.

The Style.—The general character of the style in simple ovaries has been already described. In compound ovaries there are as many styles as there are carpels; and they either remain distinct, as in the pink, or become partially united, as in the geranium, or completely consolidated to their summit, as in the lily.

When we examine a transverse section of the style with a sufficient magnifying power, we always find it hollow. The interior of the style is in fact a canal, extending from the stigma to the cavity of the ovary. This canal is sometimes open; but generally it is filled with a humid and lax parenchyma, which differs considerably from the other parenchyma of the style, and which is distinguished as the conducting tissue. This tissue spread out on the summit of the style rms that spongy surface called,—

The Stigma.—This is a glandular body, placed on the summit of the style, when there is one, or immediately on the ovary when there is no style. It is denuded of cuticle, and secretes a viscid fluid which detains the pollen grains, and causes them to emit tubes. This secretion becomes more abundant as the period of fecundation approaches.

The stigma is simple when it is connected with a single pistil; but in the compound pistil there are necessarily as many stigmas as there are carpels united together. When the ovaries and styles of all the carpels of a compound pistil are in a state of complete cohesion and consolidation, the stigma always presents a number of lobes or divisions more or less deep, which clearly indicate the number of pistils which have cohered together.

The lobes of the compound stigma are excessively variable; they may be flat and pointed, and hemispherical and blunt, smooth, or covered with salient papillæ, or with hairs simple and glandular, or with branched and plumose hairs, as in the grasses.

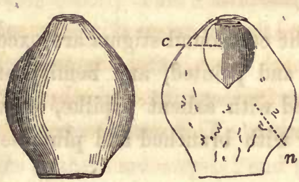
The Ovule is the body which is contained in the cavity of the ovary and attached to the placenta, and which, after impregnation, is transformed into the seed. It experiences in this transformation remarkable changes in its structure, form and position.

In order accurately to trace the development of an ovule, we must commence our observations as soon as the plant begins to form flower-buds. We shall then see in the interior of the ovary, forming on the placenta, a minute excrescence or tubercle, formed solely of cellular tissue. This gradually enlarges into a more or less obtuse conical form, constituting what has been called the nucleus of the ovule. As growth

progresses, one of the cells towards the apex of the nucleus expands, forming a cavity in its interior, termed the embryo sac, because it is in this cavity, after impregnation, that the rudimentary embryo first makes its appearance.

In the mistletoe the ovule remains in this simple and naked condition. Fig. 57 is the ovule of the mistletoe entire and in section with the embryo sac, *c*. In most plants, however, the nucleus becomes surrounded by one or more coverings during the progress of growth. These first appear around the base of the nucleus in the form of circular swellings, which gradually spread over its surface.

Fig. 57.



In some cases, as in the ovules of the Walnut, fig. 59,

Fig. 58.

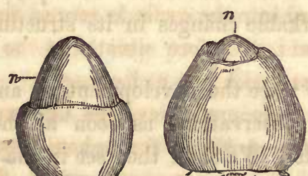
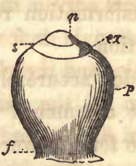


Fig. 59.



the nucleus *n*, has only one covering formed on its surface; generally, however, whilst this envelope is increasing, another envelope is formed outside of it, beginning at its base, and

overspreading its surface in precisely the same way, as is represented in Fig. 59.

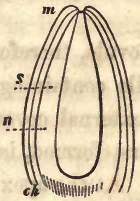
A fully developed ovule, therefore, consists of a conically-shaped nucleus of cells containing a cavity or embryo sac in its interior, with two external coverings. The one *s*, next the nucleus *n*, which is first formed, is termed the *secundine*, the other *p*, the *primine*. At the apex of the nucleus, both coverings leave an opening which has been termed the foramen or micropyle, (μικρὸς little, πύλη gate), through which the nucleus slightly projects when it is not completely covered. The opening or mouth of the primine, *ex*, is called the exostome, (εξω outside, and στόμα mouth;) that of the secundine end, the endostome (ἔνδον within). *f* is the point where the ovule is attached to the placenta.

The nucleus and its two external investments have no organic connexion with each other, excepting at the base of the ovule, where vessels pass from one into the other and unite the several parts firmly together. This common point of union is termed the *chalaza*.

The ovule is attached to the placenta either directly, when it is said to be sessile, or by means of a prolongation or umbilical cord termed the funiculus, (*funis*, a cord.) The point where this cord is inserted into the ovule is termed the hilum. The micropyle or foramen is therefore situated at the apex of the ovule, and the chalaza and hilum at its base.

When all the parts of the ovule develope uniformly, they maintain the same relative position throughout their entire growth, as they had at its commencement. Fig. 60. The chalaza *ch*, is at the hilum or base of the ovule, and the micropyle, *m*, at its apex or opposite extremity, so that a straight

Fig. 60.



line passes through their axis. In this instance the ovule is said to be orthrotropous, (ὀρθὸς, straight, and τρόπος, mode.)

This is the primitive and most simple form of all ovules, although not the most common. The ovules of the Urticaceæ or nettle tribe, of the Cistaceæ or rock-rose family, and of the Polygonaceæ or buckwheat family, are of this character.

When, however, there is an inequality in the development of the parts of the ovule, either one or the other of the following modes of growth will generally be the result.

Either the hilum and chalaza will remain together and the ovule will curve upon itself, so that the micropyle will be brought near to the hilum, and we shall have a campulitropous ovule, (καμπυλὸς curved,) as in all cruciferous plants, (Fig. 61;) or else the chalaza will elongate from the hilum and become transported to the apex of the ovule, whilst that apex by an inverse movement directs itself to the place which the chalaza has abandoned. In this case, the ovule is said to be inverted or anatropous, (ἀνατρέπω I subvert.)

The curvature of the ovule in the first instance, is to be attributed to an inequality in the development of its sides. Thus, one of the sides of the primine possesses more energy of development than the opposite side; the former therefore elongates whilst the latter remains stationary; and the resistance

Fig. 61. Fig. 62.

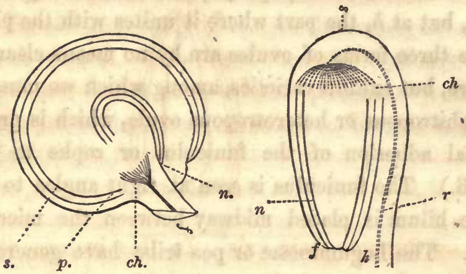


Fig. 61. Campulotropous ovule of Wall flower. (*Cheiranthus.*) *f.* The funiculus by which the ovule is attached to the placenta. *p.* The primine. *s.* The secundine. *n.* The nucleus. *ch.* The chalaza. The ovule is curved on itself, so that the micropyle is brought near to the hilum.

Fig. 62. Anatropous ovule of Dandelion (*Leontodon*). *f.* The foramen or micropyle. *h.* The hilum. *ch.* The chalaza. *n.* The nucleus. *r.* The raphe connecting the chalaza or base of the nucleus with hilum *h,* and placenta.

offered by the inert side necessarily compels the extensible one to turn round the centre of resistance, and the ovule curves upon itself.

In the other instance, since the hilum retains its place, the vascular bundle which brings it into communication with the chalaza is forced to follow the ovule in its evolution, and forms by its elongation, a cord more or less prominent within the thickness of the primine which is called the raphe, (ραφη a line.)

Some botanists think that the anatropous ovule, is simply an orthotropous ovule inverted on an elongated funiculus or podosperm, (ποῦς a foot, and σπέρμα a seed,) which is attached in the form of a raphe to one side of the ovule. But the raphe *r,* Fig. 62, appears to be an elongation of the vascular bundles which connect the chalaza with the hilum; and this view is established by the fact that in anatropous ovules, the

hilum is not seen at *s*, the part where the raphe joins the chalaza, but at *h*, the part where it unites with the placenta.

These three forms of ovules are by no means clearly defined in nature, but exhibit varieties, among which we must mention the amphitropous or heterotropous ovule, which is produced by a partial adhesion of the funiculus or raphe to the ovule, (Fig. 63.) The funiculus is seen at right angles to the ovule, and the hilum is placed midway between the micropyle and chalaza. The Leguminosæ or pea tribe have generally ovules of this character.

Anatropous ovules are the most common in plants. The orthotropous form is considered to be the condition of all ovules at the commencement of their development, and the other forms are referable to changes produced during growth. The anatropous ovule of the celandine and the campulitropous ovule of the mallow, have been traced from the orthotropous condition at the commencement of their growth, through all the intermediate stages of development.

Fig. 63.

Fig. 64.

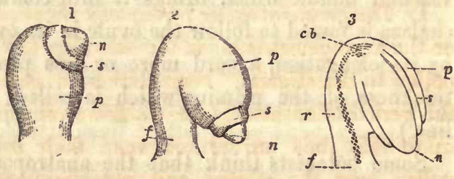


Fig. 64, is a representation of the development of the anatropous ovule of the Celandine, (Chelidonium majus.) 1 and 2, are the first stages. The primine and secundine investments are marked *p* and *s*, and the summit of the nucleus *n*. 3 is the fully developed ovule after it has executed its demi-revolution on its funiculus *f*. The reason of this singular change in the position of the ovule will appear in the next chapter.

All these changes in the structure, form and position of the ovules, are executed whilst the flower buds are forming. About

the time of the expansion of the flower, the ovules are generally fully formed and ready to receive the impregnating influence of the pollen. They have become regularly shaped usually roundish bodies fixed to the placenta by one side. They are not yet seeds, but are destined to become seeds at a future period.

CHAPTER XIII.

THE PROCESS OF FERTILIZATION OR FECUNDATION.

Functions of the stamens and pistils.—Fecundation is that function by which the pollen is brought into contact with the pistil, so as to produce within the ovule the formation of an embryo. The results of fecundation are the transformation of the ovules into seeds and of the carpels into fruits. Let us consider,—

1. *The preparatory or precursory phenomena of fecundation*, or the arrangements made for securing the application of the pollen to the stigma. Fecundation in general takes place at the period of anthesis, (ἄνθησις, flower opening.) The anthers, up to this time unruptured, open their cells, and spread the pollen over the stigma and very frequently over the other parts of the flower, and it is then that fecundation is effected.

There are however a certain number of plants among which fecundation takes place before the expansion of the floral organs. This is the case with many of the Compositæ and Aster tribe which have syngenesious stamens, the stigmas and styles of whose pistils are clothed with what botanists have

agreed to call collecting hairs. The style of these plants is at first shorter than the stamens and enclosed by the cohering anthers; as it developes it pushes its way through them, and the hairs on its surface brush the pollen out of the anther-cells, carrying it up along with them. Hence when the flowers are fully expanded we find the anthers already open and in part empty, fecundation having been accomplished.

In most cases, however, fecundation does not take place whilst the perianth encloses the sexual organs, but at the time of anthesis. When this period arrives, the opening of the floral envelopes frees the stamens from all confinement and restraint, and they take a rapid development. Their filaments elongate, and the pollen contained in the anther-cells up to this period succulent, moist, and adherent to the cell walls, becomes dry, pulverulent, and free within their cavities. About this time too, the stigma or summit of the pistil, tumefies and excretes in great abundance a viscous fluid which lubricates its surface and causes it to retain the pollen grains.

But before the pollen of the stamens can be applied to the stigma of the pistil, it is necessary that it should have some outlet or means of escape from the anther-cells. In the greatest number of cases, the cells open longitudinally through the whole extent of that furrow or groove which may be readily observed on their surface, as in the gilliflower, Sometimes, however, the dehiscence, (*dehisco*, I gape), only takes place at the upper part of the furrow, by an aperture resembling a pore, as in Pyrola chlorantha, (Fig. 66.)

In the common barberry, (Berberis,) the cells present no furrow, but a portion of their anterior surface opens in the form of valves, (Fig. 67.) In Pyxidanthera barbulata, the

anther-cells open by traverse dehiscence in the form of an operculum or lid, (Fig. 68.)

Fig. 66.

Fig. 67.

Fig. 68.

The mechanical application of the pollen to the stigma is sometimes secured by certain relative adjustments of the organs. Thus when the stamens and pistils are situated in separate flowers on the same plant, the staminate flowers are generally situated above the pistillate. The Indian corn exemplifies this arrangement. It is well known that the flowering panicle at the summit of the stem does not produce corn; these are the staminiferous flowers, from whose anthers descend clouds of pollen on the thread-like pistils, forming the silky tuft beneath. Without this pollen, the corn in the lower spike would not ripen; hence the evident design of nature in placing the pistillate below the staminate spike of flowers.

In pendulous and upright flowers, the filaments of the stamens and the style of the pistil are so developed as to bring the anthers and stigma into the most favorable relative position for communicating with each other. This is beautifully exemplified in the ladies ear-drop, (Fuchsia.) Within the pendulous corolla of this flower, we have an adjustment of the sexual organs with an evident reference to their mutual action on each other. The filaments of the stamens are short and the

style of the pistil is considerably elongated, and its lubricated and viscid stigma is brought below the anthers ready to receive the falling pollen. In upright flowers we have a reverse arrangement of the parts; for the style of the pistil is in a great measure suppressed, and the filaments of the stamens are so developed as to place the anthers above the stigmatic surface.

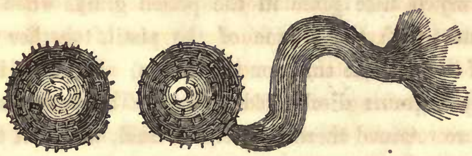
In many plants fecundation is effected by certain special movements of the male or female organs of the flower. The flowers of the mountain laurel (Kalmia) are, in this respect, especially deserving of examination. The corollas of the Kalmia are rotate or wheel-shaped, and have ten stamens. The anthers of these stamens, before the flowers expand, are contained in ten little cavities or depressions in the side of each corolla, where they are secured by a viscid secretion; when the corollas open, the filaments are bent back by the confinement of their anthers, like so many springs, in which condition they remain until the pollen in the anther-cells becomes ripe, and absorbs the secretion. The anthers becoming suddenly liberated by this means from their confinement, fly up from their cavities with such force as to eject their pollen on the stigma of the pistil. The slightest touch with the point of a needle, or the feet of an insect crawling over their reflexed filaments, will produce the same effects, if the pollen is mature.

In the same manner, the stamens of the common barberry spring to the pistil if the lower part of their filaments is touched, and seldom fail in making the movement to throw a quantity of pollen on its stigma. The stamens of the Rue, of some of the Saxifrages, and of Parnassia palustris, a rare and beautiful snow-white swamp flower, do this in succession, first

one and then the other approaching the pistil and discharging upon it the polliniferous contents of their anthers.

When grains of pollen are thrown on water, the absorption of the fluid is so rapid, that they burst, and a thick liquid escapes from them which spreads itself over the surface of the water. This thick liquid, in fig. 69, is seen escaping from one

Fig. 69.



of the pollen grains of Ipomœa hederacea, and is the fecundating matter of the grain. The action of the pollen is therefore liable to be frustrated by wet weather. This evil is guarded against by the property which the anther-cells possess of opening only in fine weather, as well as by the action of the floral envelopes, which in some plants appear to be exceedingly hygrometrical, enveloping the sexual organs on the slightest appearance of any humidity in the atmosphere. The flowers of the red chickweed (Anagallis) are a very remarkable illustration of this phenomena.

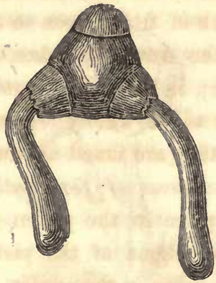
In this view too the economy of various aquatic plants is exceedingly interesting, as for instance the pondweeds (Potamogeton.) These plants live wholly submerged in the water; but at the time of flowering, the peduncles or flower stalks elongate so as to raise their flowers to the surface on which they may be seen floating. The act of fertilization is thus accomplished in the open air, and the ovaries are again drawn beneath the water, where the seed ripens. The peduncles of

the white water lily, Nelumbium, and Brazenia peltata, sometimes attain the length of from fifteen to twenty feet along the shores of some of the American lakes, so as to bring their flowers to the surface; in fact, the length of the peduncle of these plants appears to be wholly regulated by the depth of the waters in which they are found floating.

The essential phenomena of fecundation, consist in those changes which take place in the pollen grains when brought into contact with the stigma of the pistil, together with the action of the pollenic tubes on the ovules. We have intimated that pollen grains discharged from the anther-cells on the stigma, are retained there by a viscid fluid, which at this time most plentifully bedews the stigmatic surface. Very soon we see them swell out, as they absorb this fluid, those which are elliptical or elongated becoming almost spherical. At the end of a certain time, consisting of a few hours for some species, and many days for others, the thin and highly extensible intine or inner coat of the pollen grain is seen protruding in the form of a tubular or vermiform appendage.

The mode of dehiscence of the pollen grains is always determined by their structure. Those which present pores, grooves, or folds on their exterior surface, usually emit their tubes at these points. The number of tubes emitted from pollen grains is very variable; sometimes we see only one, and occasionally two or three, as in the triangular pollen of the evening primrose (Œnothera) Fig. 70. Amici was able to detect from twenty-six to thirty tubes which were protruded from the same cell. The number of tubes must necessarily bear some relation to the number of pores when these exist, and we know that they are sometimes very numerous. The pollen tubes are filled with a fecundating fluid termed fovillæ, and it is easy to

Fig. 70.



see through their thin transparent walls the movements of the microscopical corpuscles which it contains.

As soon as the pollenic tubes have been protruded from the pollen grain, they penetrate the loose cellular tissue which constitutes the mass of the stigma, known as the conducting tissue, and insinuating themselves amongst the interspaces of its cells where they find an abundance of moisture, they grow downwards through the central part of the style until they reach its base, a distance in some cases of several inches. Hence by making a longitudinal section of the pistil we are able to find these tubes and to trace their course.

The pollen tubes may be readily inspected under the microscope in many plants, and in none more readily than in the Asclepias or milkweed. In that family the pollen grains cohere together in masses termed pollinia, and their united tubes are protruded, and consequently are of such a size as to be easily perceived with a very moderate magnifying power. Fig. 71.

The action of the pollenic tubes on the ovules. At the time that fecundation is operating, and the pollenic tube is being elaborated, the ovules are organized into a suitable form for its

Fig. 71.

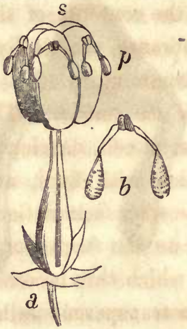


Fig. 71. Pistil of Asclepias *a*, with pollen masses *p*, adhering to the stigma *s*. *b*. Separate pollen masses united by a gland like body.

reception. We have seen that the nucleus is covered by two membranes, called the primine and secundine, and that at the "apex of the nucleus both coverings leave an opening which has been termed the foramen or micropyle." Now this opening, or the nucleus projecting beyond it, is the ultimate destination of the pollen tube. Before its arrival, however, one of the cells towards the summit of the nucleus expands and thus creates a cavity in its interior which is called the embryo sac, because it is in the interior of this sac that the embryonal vesicle first makes its appearance in the upper part of the cavity. It is at first a simple cell which insensibly elongates, and by the formation of transverse septa forms itself into a sort of confervoid tube. The terminating cell of this tube enlarges and forms the embryonal vesicle. The pollen tube, having arrived at the base of the style, enters the ovary, and makes its way through the micropyle or orifice of the ovule, penetrating the tissue of the nucleus till it reaches the embryo sac. Fecundation appears to be produced by the simple contact of

the pollen tube with the embryo sac, and the imbibition by the embryonal vesicle of the contents of the pollen grain through the intervening membranes, the vitally active contents of the two cells being thus commingled.

The development of the embryo. The embryonic vesicle is at first simply a spherical cell, developed at the end of the suspensory filament, filled with fluid, and containing granular matter. A little time after fecundation, a longitudinal septum, in the same direction as the suspensor, is seen to form across the cavity of the cell, which thus becomes divided into two cells. Very soon each of these two cells is divided into two others, and all prove successively the same segmentation. The necessary result of this is, a little mass of cellular tissue limited exteriorly by the walls of the primitive cell, forming the embryonal vesicle. It is this mass of cellular tissue which by degrees organizes itself into an embryo.

In some plants it remains in this primitive and somewhat amorphous state, being simply a mass of cells without distinction of organization or of parts. This is its condition in all Acotyledonous or Cryptogamous plants, where the embryo bears the special name of spore. In Phanerogamous plants, however, this mass of cells assumes a more highly developed state. The cells in the upper part of the mass which are immediately connected with the suspensory filament, elongate into a somewhat conoid body, which in the perfect embryo constitutes the radicle, whilst the cells in the lower part soon begin to present traces of their future cotyledonary character, the end farthest from the suspensor becoming two-lobed in Dicotyledonous, and one-lobed in Monocotyledonous embryos. (κοτυληδὼν, the name of a plant having leaves like seed-lobes.)

Fig. 72,* shows the different stages in the development of

Fig. 72.

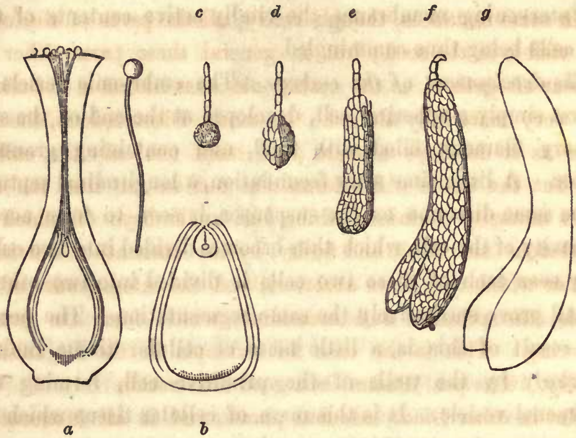


Fig. 72. *a.* **Vertical section of the pistil of Polygonum after fertilization, showing, the pollen grains adherent to the stigma with their tubes passing down the style, the erect orthotropous ovule in the interior of the ovary, and the nascent embryo sac. A pollen grain detached with its tube.** *b.* **The ovule more highly magnified, showing the embryonal vesicle formed in the interior of the sac at a later period.** *c.* **The nascent embryo and its suspensor removed from the sac, and more magnified.** *d, e, f.* **The embryo in succeeding stages of development.** *g.* **The embryo as it exists in the seed.**

the Dicotyledonous embryo of a species of Polygonum. Only one ovule is contained in the ovary of the pistil, and this is orthotropous. The plant has therefore been very properly selected for illustration on account of the simplicity of its pistil. The process is the same, although more complicated when the ovules are more numerous.

The change of the ovule into the seed. It will be perceived that as the embryo is developed, the suspensory filament by which it is attached to the summit of the embryo sac is gradually absorbed; also that great changes must necessarily

* "Botanical Text-Book," by Asa Gray, M. D.

take place in the structure of the ovule as the embryo forms in its interior.

In some instances, though rarely, all the parts of the ovule are visible in the seed; but in general these parts either disappear altogether, as the embryonic mass increases in bulk, or are very materially altered. In many Dicotyledons, the embryo as it develops absorbs into itself not only the embryo sac but the tissue which forms the nucleus, so that the seed at its maturity contains nothing but an embryo of which the cotyledons are thick and fleshy, by the amount of nutritious matter which they have absorbed, and the integuments of the ovule, the primine and secundine, which form its general covering. This is the case for example in the Leguminous family. The pea (Pisum) is a good illustration.

But in other Dicotyledonous plants, and in all Monocotyledons, the nutriment which the ovule contained in its interior is unabsorbed into the embryo, which does not increase much in bulk, and encroaches very slightly on the cells of the nucleus. These cells therefore become filled with a deposit of solid matter termed albumen, in the midst of which the embryo is embedded.

Seeds in which the embryo occupies the entire seed are called ex-albuminous (*ex* without), as the Compositæ, Cruciferæ, and Leguminosæ, whilst others having separate albumen are albuminous. The larger the quantity of albumen in the seed, the smaller the embryo.

Soon after fertilization, the pollen tube withers from above downwards, the foramen or micropyle of the ovule closes, and when the embryo is fully developed within it, the ovule becomes the seed and the ovary the fruit.

The changes which manifest themselves in the flower and in

the other sexual organs of the plant after fecundation. A plant in every stage of its existence is a beautiful subject for contemplation, but particularly at the close of the period of its life. What, when its leaves are withering and falling from its stem! when its flowers are losing their brilliant hues and inimitable coloring! and when the whole vegetable economy of the plant is languishing! Yes, even then it becomes, if possible, an object of deeper admiration. Why do the leaves fall from its stem? Because food is no longer required to be taken from the atmosphere. Why do the flowers lose their beauty, the petals detach themselves and fall, and even the stamens experience the same degradation? It is because these parts of the plant have fulfilled their allotted functions. No leaf or flower fades or falls in nature before it has accomplished the purposes of its creation. You see that the pistil alone remains in the centre of the flower. But the style and stigma are now useless to the plant, and therefore they disappear equally with the other parts. The ovary alone is persistent, since it is in its bosom that nature has carefully deposited the embryo or seed which contains in itself the rudiments of future generations.

A little time after fecundation, we see the ovary increase in size, the ovules which it encloses being converted into seeds containing an embryo, and very soon the ovary has acquired all the characters proper to constitute it a fruit.

CHAPTER XIV.

ON THE VARIOUS MODIFICATIONS OF THE FLORAL ORGANS.

HITHERTO we have studied the flower, in the higher degrees of its development, in a complete, symmetrical, and regular state. We have to a certain extent supposed that there was no disturbance of this regularity. Thus we have described the flower as composed of all its verticils, the calyx, the corolla, the stamens, and pistils—or in a complete state. We have supposed the parts of each verticil to be alike in size and shape, or the flower to be regular, and each verticil to contain the same number of pieces or a multiple of that number, separate from each other and alternating among themselves—or the flower to be symmetrical.

Fig. 73.

To obtain an exact view of the symmetry of a flower we must observe it whilst in the bud, and trace it out in the form of a horizontal section, as if all the verticils had been deprived of height and sunk down to the same plane. We are thus enabled to see at a glance the position of the different parts of the flower. This theoretical section is called a diagram. Fig. 73 is a diagram of a complete, symmetrical, and regular

flower, that of a Crassula, showing the alternation of the parts of each verticil, and also an equality in the number of pieces of which each verticil is composed. All the verticils are separate from each other, and the parts of each are equally distinct.

Assuming this complete and symmetrical flower to be the normal plan or type on which flowers are constructed, when we examine the various plants around us we find that most of them are in an abnormal state, and we are able only to cite a very small number whose flowers preserve this complete, symmetrical, and regular condition. In the immense majority of cases the regularity is destroyed, and the symmetry disguised by a variety of causes. The following are those which act the most frequently :—

One or more additional verticils of the same organs have been developed.—Thus in Ranunculus we have five sepals, five petals, and numerous stamens and pistils; this is occasioned by the development of additional whorls of stamens and pistils. A multiplication of stamens also occurs in other plants, as in Anemone and Hypericum.

The composition of the flower is somewhat different in Dicotyledons and Monocotyledons. In the first, it is the number five or one of its multiples which commonly predominates. Thus the calyx is generally composed of five sepals, the corolla of five petals, the androecium of five, ten, or twenty stamens, and the gymnœcium of five pistils or some multiple of that number, the parts of all the extra verticils alternating with each other. Fig. 74 is a diagram of the flower of the Ranunculus with five sepals, five petals, and numerous stamens and carpels in alternating rows of five each. This orderly distribution of a certain number of parts is called symmetry, and a

Fig. 74.

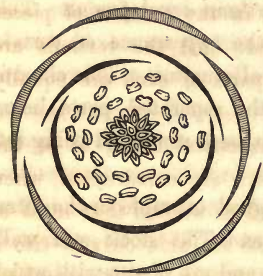
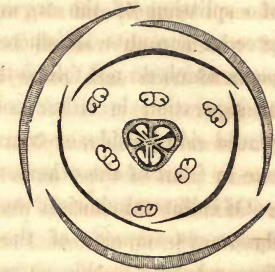


Fig. 75.



flower in which the parts are arranged in fives is said to be pentamerous, (πέντε five, μέρος a part.)

In monocotyledons, on the contrary, we observe more frequently the number three or one of its multiples, or the flower is trimerous, (τρεῖς three, μέρος a part.) Fig. 75 is a good illustration. It is a diagram of the flower of the snow-flake, (Leucojum), a monocotyledonous plant, having three sepals, three petals, six stamens in two alternating rows, and three carpels. This flower is symmetrical, complete, regular, and trimerous.

The number of extra verticils which are developed is sometimes very considerable, as in the Cactus and white water-lily, (Nymphæa.) In such circumstances it is easy to perceive that the disposition by verticils is only apparent and that the floral leaves are arranged in a spiral about the axis of growth. The spiral law not only produces the orderly distribution of the leaves about the stem, but ensures the same symmetry in the floral organs, producing that regular alternation of the parts of each verticil, and in these plants a very perceptible spiral arrangement of them.

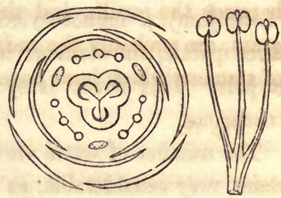
The parts of the floral organs may have been increased by

deduplication or chorization, (χωρίζω, I separate,) that is, by the splitting of the organs during their development. This process accounts satisfactorily for the appearance of certain parts which do not follow the law of alternation. This chorisis or separation is either collateral, the separated parts being placed side by side, or transverse, the parts separated being left one in front of the other.

Of collateral chorisis we have a good example in the tetradynamous stamens of the Cruciferæ. The stock and wallflower belong to this natural order, and are plants with which all are familiar. Fig. 76 is a diagram of a flower of the com-

Fig. 76.

Fig. 77.



mon stock, (Matthiola incana,) showing a calyx with four sepals, a corolla with four petals, but the stamens are six: four long and two short; the former, placed together in pairs as shown in the diagram, are supposed to have been originally

one stamen which has been split into two by collateral chorisis, thus producing the want of symmetry in the stamineal circle. And that this supposition has some foundation is evident from what we see in Streptanthus hyacinthoides, (Fig. 76,) one of the wild flowers of Texas. In this plant the chorization has been arrested before its completion, so that in the place of two stamens we see a forked filament bearing two anthers.

The beautiful marsh flower, called by botanists the Elodæa Virginica, (Fig. 77,) furnishes us with another sample of collateral chorisis. The ground plan of this flower, *a*, shows it to be both pentamerous and trimerous in its organization, its floral envelopes consisting of five sepals and petals, whilst its andrœcium and gymnœcium consist of nine stamens and three pistils, the nine stamens being triadelphous, and evidently formed by collateral chorization out of three, as shown at *b*. The three glands which occupy an intermediate position between the corolla and the andrœcium, as shown in the diagram, are probably the rudimentary traces of an exterior circle of stamens which have been rendered abortive.

Fig. 78.

Fig. 79.

Fig. 80.

Transverse chorization, or the separation of a lamina from organs already formed, is believed to take place in the case of

appendages to petals. In Ranunculus, transverse chorization or dilamination of the petals, produces a scale-like body at their base, (Fig. 78,) and a two-lobed appendage on the inside of the lamina of the petals of Silene, (Fig. 79;) and in Parnassia Caroliniana this accessory structure assumes at the base of the petal the appearance of abortive stamens, (Fig. 80.) These bodies, however, are situated opposite to the petals as shown in the diagram, and the stamens alternate with the lobes of the corolla and are therefore in their normal position, so that these appendages are certainly not stamens, but are produced by the transverse chorization or dilamination of the petals opposite to which they are placed.

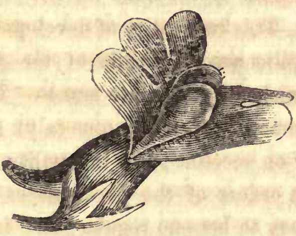
One or more pieces of the same verticil may have united among themselves, or the whole of the pieces of the same verticils may have become coherent. These unions are extremely frequent, and may manifest themselves in all the floral verticils. Thus the sepals may become soldered together and form a monsepalous calyx, or the petals, a monopetalous corolla; and in like manner the stamens may unite together by their filaments and become monadelphous, diadelphous, or polyadelphous, or by their anthers and become synantherous or syngenesious; and lastly, the carpels may become united together by their ovaries, or by their ovaries, styles and stigmas, so as to constitute an apparently unique pistil. These different kinds of soldering are very common amongst flowers, and, generally speaking, they do not alter their symmetry and regularity.

But, in other flowers, it is more difficult to perceive at first sight what it is that disturbs their regularity and symmetry, as for instance when two or more pieces of the same verticil become soldered together. In general, however, with a little care, the number of petals or sepals which have united, and

the nature and extent of the soldering, may be easily detected. For example, if the number of petals or divisions of a monopetalous corolla do not correspond to those of the calyx, and this difference is due to the cohesion of one or more of the petals, the nature of the soldering may be readily detected by the number of the midribs. Thus when two petals have united in the place of one nerve, we shall detect two collateral nerves in the petal, or three, one of which will be in the middle when the compound petal results from the union of three petals. In general, the number of midribs in the compound petal or sepal will be sufficient to show the number of separate pieces which have become soldered together.

Let us take for illustration and analysis, the flower of the common Snap-dragon (Linaria,) (Fig. 81.) The calyx is mo-

Fig. 81.



nosepalous, and has five equal divisions. The corolla is monopetalous with two unequal lips, of which the superior represents two petals, the inferior, three, whose midrib is prolonged into a spur. The stamens are four in number, two long, and two short; the former being situated between the middle petal and the two lateral petals of the lower lip, the latter being placed in the fissures which separate the two lips. At the base of the superior lip may be detected a little filament representing the fifth stamen.

In certain circumstances the Linarias develope themselves with all their petals similar to the middle petal of the lower lip, and the verticil presents then a perfectly regular figure. It is a corolla, with five lobes and five spurs, perfectly equal among themselves. At the same time, the filament placed at the base of the superior lip developes itself into a stamen organized like the others, which, although unequal in their habitual condition, are now absolutely the same in length, after the manner of a flower provided with five symmetrical stamens.

The name peloria (πελώριος monstrous,) has been given to this kind of metamorphosis; but modern botanists, far from regarding this change as a digression of nature, consider it as a return to the normal state of the flower. To their eyes, an irregular flower is an habitual alteration, and a pelorious flower is a flower put into regular order.

The parts or organs of the same verticil may have been unequally developed. This inequality of development is strikingly shown in the papilionaceous corolla of the pea, the parts of which are distinguished by separate names. This plant has all the parts of a symmetrical pentamerous calyx and corolla, only they are irregular on account of an inequality in their development. In certain orders of the papilionacea the corolla has, however, a tendency to become regular, and in Cassia, the five petals differ very little from each other either in shape or size.

One or more floral verticils may have united with each other. Thus the stamens are united to the calyx in the rose and blackberry, and to all monopetalous corollas. So also the calyx is often united to the ovary as in the apple, in which case the sepals, petals, stamens and pistils appear to grow out of its summit, and the ovary is said to be inferior, as in the honeysuckle and dog-wood. More rarely, the two interior verticils,

the stamens and carpels, cohere together. This case, nevertheless, presents itself in Orchideous plants, which constitute the true gynandrous plants of Linnæus.

The adherence of the different verticils among themselves is called their insertion. It is above all essential to study the insertion of the stamens, as it furnishes for the natural co-ordination of plants, characters of the first value. Three modes of insertion have been distinguished, called hypogynous (ὑπο under, γυνὴ female or pistil), perigynous (περί around), and epigynous (ἐπί upon.)

The hypogynical insertion is that in which the stamens are inserted upon the ovary, which is therefore necessarily free and superior, as for instance, in the Ranunculus. This kind of insertion is readily recognized in this, that we are able to remove the calyx without carrying the stamens away at the same time.

The perigynical insertion takes place when the stamens are attached to the calyx and surround the ovary, as in the strawberry (Fragaria.) This is distinguished by this, that when we remove the calyx, we necessarily remove the stamens at the same time, which are inserted on it.

The epigynical insertion is that in which the stamens are inserted upon the superior part of the ovary, which necessarily happens whenever the ovary is inferior.

One or more organs of the same verticil, may have been suppressed or rendered abortive. Abortions and suppressions contribute more than any other cause to destroy the symmetry and regularity of the floral organs. Abortion is the state of an organ which, after having commenced to form, is arrested in its evolution and remains reduced to a species of stump, sometimes a gland ; suppression indicates the total absence of the organ, which has not even commenced to develope itself.

The symmetry of the flower is frequently destroyed by the abortion of one or more organs of the same verticil. In the natural order Scrophulariaceæ we are able to follow, step by step, the progressive abortion and final suppression of an organ, as for instance, a stamen, by examining the flowers of its different genera. Thus if we look at the flower of the common mullein (Verbascum) which is placed at the head of the order, we shall find that it is symmetrical and pentamerous although somewhat irregular in its construction, having a calyx of five sepals, a corolla of five petals soldered together, the lobes broad, rounded, and a little unequal; the stamens are five, and alternate with the lobes of the corolla; but one of the stamens is a great deal less than the others; it has proved already a certain degree of arrest in its development. In Pentstemon the anther is abortive, and the stamen appears in the form of a bearded filament. In Linaria it may be detected in the form of a little filament at the base of the superior lip of the corolla. If now we examine a flower of the Scrophularia we shall observe no more than four stamens. However, between the two upper lobes of the corolla, on its interior surface we shall find a little glandular scale, occupying the very place of the missing stamen, and of which it is not difficult to recognise the nature Lastly, if we open a flower of the Digitalis or Antirrhinum, we shall find no trace of the fifth stamen, which has completely disappeared.

The abortion and suppression of the staminal verticil is carried still further in other genera of the same family. Thus Gratiola Virginica has a calyx of five sepals, five petals united almost to their tips, and only two perfect stamens, the three others having been entirely suppressed. But we can satisfy ourselves that this abortion and ultimate suppression of the

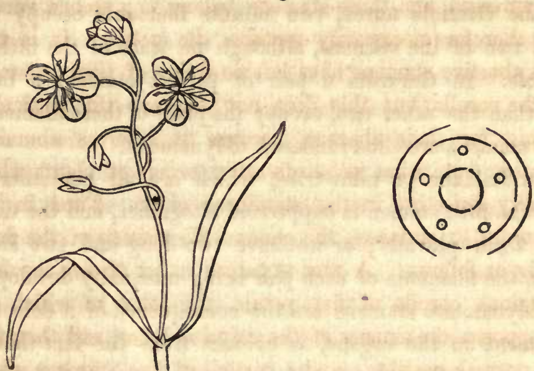
organs has been gradual, for in another species of the same genus, the Gratiola aurea, two minute filaments occupy the place of two of the stamens, although no trace of the fifth is observable. In Gerardia a pair of perfect stamens a little shorter than the other two, occupy the place of these filaments, and the stamens are thus rendered didynamous.

In the Labiatæ or mint tribe, which are all pentamerous flowers, the fifth stamen is suppressed altogether, and the didynamous form prevails; or we have two long and two short stamens, the filaments of each pair being unequally developed. That didynamous stamens are the consequence of a defective development of the organs, is evident from the fact that in other genera of the same family the development of the organs has been arrested at an earlier stage, so that the two short stamens are either reduced to mere filaments, or are absent altogether from the corolla, the flower being strictly speaking diandrous.

The symmetry and regularity of the floral organs is more frequently disturbed by the defective development or entire suppression of one or more of the organs of a verticil, than by any other cause. Such deviations from the normal structure are very common, in fact almost any flower will discover them to the intelligent student, and the principle when once clearly understood may be extended almost indefinitely.

We close our illustrations of this topic with the following analysis of the Spring beauty (Claytonia), a very common but remarkably unsymmetrical flower. (Fig. 82) is a diagram showing the flower and its ground plan. It will be perceived that the flower is complete, for the four verticils are present, some of them being partially but not entirely suppressed; that the flower is regular, for all the pieces of each floral verticil are

Fig. 82.



equally developed, but that it is remarkably unsymmetrical, for only two of the four circles have the same number of members, and one of them, viz., the staminate circle is in an abnormal position; for instead of alternating with the petals, we find the stamens in this flower placed directly opposite the petals. The diagram shows a calyx with two sepals, but as the normal construction of the flower is evidently pentamerous, three of the sepals have been suppressed, and the two which have been developed, have evidently obtained possession of the place which the three by their absence had left void. Within the calycine verticil, are five equally developed petals alternating with the sepals of the calyx, and which are therefore regular and normal in their growth. Within and *opposite* the petals we find five stamens. The number of the stamens is normal, but not their position. Here is an evident departure from that law of alternation which usually manifests itself in the relative position of the pieces of the floral verticils, when they follow each other directly in the flower.

It would appear from this, that a verticil of stamens has been suppressed, and these stamens belong to a second verticil and are therefore necessarily opposite the petals. It is true that the abortive stamens have left no traces of their existence within the corolla, but this does not disprove this method of accounting for their absence, because it receives abundant confirmation from what we see in other orders of plants which are equally defective in the stamineal circle. Thus in the natural order Primulaceæ, the general disposition of the floral organs is as follows. A monosepalous calyx of five sepals, a monopetalous corolla of five petals, the lobes of which are situate opposite the sinuses of the calycine lobes, and therefore in their normal position; and a verticil of five stamens which are directly opposite the petals. The law of alternation is therefore defective in the staminical circle. We account for the phenomena in the same manner as we explain it in Claytonia, on the theoretical supposition that the primary alternating verticil of stamens is generally suppressed in this family. We examine the other genera of this family for confirmation of our theory, and we find, that although the primary verticil of stamens is suppressed in most of the corollas of the order, yet this very verticil is present in some of them in an intermediate stage of development. Thus in Samolus floribundus, for example, there are found in the sinuses of the corolla, in the normal position of the absent verticil, five sterile filaments which are unquestionably these very stamens in a rudimentary condition. When, therefore, we find in the Claytonia and other plants, a verticil of stamens opposite the petals of the corolla, instead of alternating with those petals, we are justified in supposing that the primary alternating verticil has been suppressed, although we may not be able to recognize any traces of its existence in the corolla.

Lastly, in the centre of the flower of the Claytonia, there are three pistils; two have therefore been suppressed.

One or more entire verticils may have been wholly suppressed. We have already said that the complete flower consists of four verticils of metamorphosed leaves, viz., the calyx, corolla, stamens and pistils: now if any one of these verticils be absent, the flower is incomplete. Deviations resulting from the non-production of the verticils are not uncommon, and may affect any of the floral organs. Thus the calyx is reduced to an obscure ring or border in the holly and dogwood, and is suppressed altogether in the prickly ash, (Zanthoxyllum.) We infer that it is the corolla which remains in this flower because the five stamens alternate with it. In other instances the corolla is suppressed and the calyx remains as in Anemone and Clematis.

It is proper to remark here, that where there is only one floral envelope, the law of alternation will enable us to detect whether it is a calyx or a corolla. Thus if the corolla is suppressed, it is easy to see that the two verticils between which the corolla is developed will have their parts opposite, that is to say, the andrœcium and the calyx. This is their natural position, since the stamens alternating with the petals are necessarily placed opposite to the sepals; and therefore when we find them in this position and only one floral envelope, we may conclude that envelope to be the calyx and the petals, to have been suppressed, whatever may be its color and hue. If, on the contrary, there is a single envelope with which the stamens alternate, we may conclude that it is the calyx which has been suppressed, and that the colored envelope is a true corolla. This appears to be an easy way of settling this question where other methods fail.

Not unfrequently, however, the floral envelope which has disappeared, has left traces of its existence sufficient to disclose the character of that which remains. We know that the proper place of the petals is between the sepals and the stamens, and if we find anything occupying their position, we are at once convinced from the laws of development which are so clearly and beautifully expressed in other genera, that it is the same organ in an abortive or rudimentary condition. Thus the flower of Pulsatilla patens has only one floral envelope. In the place, however, usually occupied by the petals, we find certain abortive gland-like stamens, which are in fact the rudiments of the suppressed petals; this therefore decides the envelope to be a calyx.

In some plants, such as nettles and Chenopodiums, the floral envelopes are green and inconspicuous, and in the grasses they are suppressed altogether, their places being supplied by rudimentary leaves or bracts. When this is the case, the flower ceases to attract popular attention. The world attaches the idea of a flower to that part of a plant which is usually colored with tints more or less brilliant, which makes its appearance generally before the seed, and after delighting our senses with its fragrance and beauty for a brief space of time, is replaced by the fruit or seed. But such flowers are only characteristic of the more perfect races of plants. The botanist stops not at these appearances, for to him the flower is often deprived of them. The student must learn to recognize the flower in the lower degrees of its development.

When both stamens and pistils are present in the same flower, it is said to be hermaphrodite and complete. When on the contrary, the flower contains stamens only, or pistils only, it is denominated unisexual, and is male or female according

as the former or the latter only are found within the floral envelopes.

When the stamens and pistils are in separate flowers on the same plant, as in the castor-oil plant, (Ricinus,) and Indian corn, (Zea mays,) the flowers are monœcious, (*μόνος* one, *οἰκιον* habitation.) When the staminate flowers are on one plant and the pistillate flowers on another, the flowers are diœcious (*δις* twice,) as in the nettle and hop; and when the same plant developes both unisexual and hermaphrodite flowers, they are polygamous (*πολύς* many, *γάμος* marriage,) as in the maple and Euphorbia. In the marginal flowers of Hydrangea arborescens, and Viburnum opulus, the Snow-ball tree, the essential organs, the stamens and pistils, are entirely suppressed; these flowers are therefore necessarily sterile.

The following diagrams will illustrate the several stages in the suppression of the floral organs of Phanerogamous plants, until we arrive at their minimum reduction, when any farther suppression would render the production of an embryo or seed impossible.

Fig. 83.

Fig. 83, is a representation of the flower of the Saururus cernuus or Lizard's tail. The flowers of this plant are perfect, and are developed in racemes or spikes, but destitute of all floral envelopes, a simple scale or bract supplying their place.

Fig. 84.

Fig. 85.

This plant is common along the margins of streams and ponds, and may be found in bloom in the month of June.

Fig. 84, is the stinging nettle, (Urtica,) bearing clusters of greenish inconspicuous unisexual flowers *a*, in the axils of its leaves. Fig 86, one of the male flowers magnified. Its perianth is a simple calyx of four sepals, within which are four stamens opposite to the sepals, situated on the receptacle, and

this relation of parts leads at once to the detection of the fact that the corolla has been suppressed. The perianth of the female flower is also a simple calyx, consisting of four very unequal sepals, the two outer small, the inner foliaceous, enclosing a single pistil.

Fig. 86.

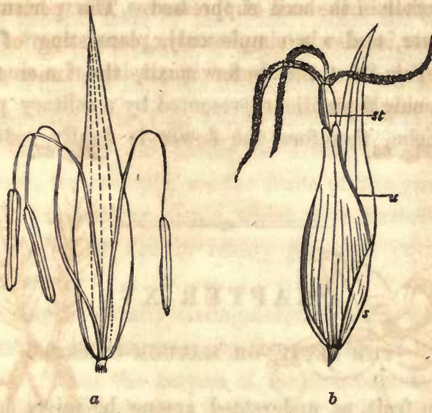
Fig. 87.

Fig. 85, shows a compound spike of wheat, (Triticum,) with numerous spikelets or flowers arranged along the axis in a zigzag form. Fig. 87, one of these spikelets magnified, and deprived of its glumes, showing the three stamens *a*, hanging by long thread-like filaments, and the feathery styles of the pistil within two bracts *sq*. The flower in this case is hermaphrodite.

The flower is therefore still further reduced in the sedges (Carices,) which are equally without floral envelopes, and are unisexual.

Fig. 88, shows the monœcious flowers of a species of Carex. *a*. One of the staminate flowers, consisting of a single glume or scale and three stamens. *b*. One of the pistillate flowers.

Fig. 88.



This pistil is covered by an urceolate glumaceous bag marked *u*, called a perigynium. There is one style *st*, with three stigmas at its summit.

Fig. 89.

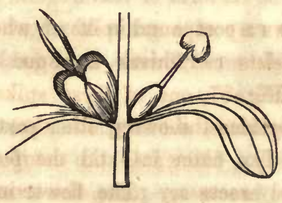


Fig. 89, is a representation of a common, though exceedingly interesting aquatic plant, the Callitriche verna, (καλός beautiful, and θριξ hair, in allusion to its capillary and tufted stems.) The lower leaves of the stem are immersed and linear, the upper floating and spatulate. The flowers are polygamous, unisexual and hermaphrodite flowers growing together on the same plant. They are without either calyx and corolla, have

not even a bract, and consist of a single stamen and pistil placed together in the axil of the leaves, when hermaphrodite and complete, and when unisexual, placed apart from each other. In Fig. 89, the male flower consists of a single stamen and the female flower is represented by a solitary pistil. In the Callitriche, therefore, the flower is finally reduced to a minimum.

CHAPTER XV.

THE FRUIT, OR MATURE OVARY.

THE term fruit, as understood among botanists, has a more extended signification than its meaning in ordinary language. It is applied by them to the fecundated and mature ovary enclosing seeds, capable of germinating and reproducing the plant, whatever be its form or texture, and whether it be edible or not. In this respect a grain of wheat or corn, or the pericarp of the sun-flower or thistle, is as much a fruit as a peach, gooseberry, or melon.

Very often, besides the ovary, other parts of the flower, and especially the calyx, enter into the composition of the fruit; but these are only accessory parts, the term fruit being strictly applicable only to the ovary.

The fruit is composed of two parts, the pericarp (*περί* around, *καρπὸς* fruit,) and the seed or seeds. The pericarp is formed by the walls of the ovary itself; the seeds are the ovules fecundated and containing an embryo. Let us consider each of these parts in succession.

THE PERICARP.—The pericarp is that part of the fruit

which is formed by the walls of the ovary, and which determines the general form of the fruit. Since the walls of the ovary constitute the pericarp, it must be constantly present in all fruits. When the fruit is a single cell and contains only one seed, the pericarp is so thin and is united so completely with the seed, that they can hardly be distinguished from each other. Such, for example, are the fruits of the grasses, Cyperaceæ, and syngenesious plants, which were formerly regarded as seeds, but which are in reality pericarps or seed-vessels enclosing a seed.

A fruit may be usually distinguished from a seed, or other organ assuming its character, by the presence of some vestige of the style. Thus the carpels of the Ranunculus, (Fig. 90,)

Fig. 90.

Fig. 90. Carpels of the Ranunculus with a few stamens, the calyx and corolla having been removed. One of the carpels magnified, showing it to be a single-seeded vessel with the pericarp applied close to the seed. Such fruits resemble seeds in appearance, the style and stigma, *s*, aid in distinguishing them from seeds.

which are vulgarly regarded as seeds, are at once determined to be seed-vessels by their apiculate summit, the vestige of the style. In the same manner we discover that the strawberry is not a single fruit, but an enlarged fleshy receptacle bearing the simple fruits at its surface. (Fig. 91.)

The pericarp, like the leaves from which it proceeds, is composed of two plates of epidermis, between which exists a

Fig. 91.

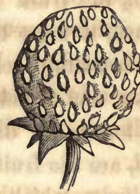


Fig. 91. Fruit of strawberry, (Fragaria vesca,) showing the carpels or achenia on the surface of its enlarged and fleshy receptacle. Each achenium has a style and stigma, and is thus at once distinguished from a seed. The calyx is seen at the base of the receptacle.

celluło-vascular bed of fibres and parenchyma. The exterior membrane of the pericarp is called the epicarp, (ἐπὶ upon, καρπὸς fruit,) and corresponds to the lower epidermis of the leaf. This membrane is ordinarily very thin, and is easily removed, especially in succulent fruits, such as the peach or plum. The interior membrane of the pericarp immediately surrounding the seed, is called the endocarp, (ἔνδον within,) and is equivalent to the upper epidermis of the leaf. It is usually thin and membranaceous, and sometimes appears like parchment, as in the pea and apple. In the peach and plum it takes a ligneous consistence, and forms the stone or putamen, (*putamen* a shell,) immediately investing the kernel or seed of these fruits. The intermediate tissue of the pericarp between the epicarp and the endocarp, which represents the parenchyma of the leaf, is called the mesocarp, (μεσος middle.) The mesocarp is more or less succulent, according to the proportionate development of its two constituents, fibres and parenchyma. It is very much developed in fleshy fruits, forming their flesh or pulp, as in the peach and plum, and hence it has been sometimes called the sarcocarp, (σὰρξ flesh.)

But sometimes the mesocarp is excessively thin, in dry fruits for example, such as the pod of the pea, or the fruit of the gilliflower. In the nut the three parts are blended together; in the peach they remain separate. In the latter fruit the epicarp forms the skin, the mesocarp the fruit or edible part of the peach, and the endocarp, the stone in its centre which covers the kernel and seed.

Whatever may be the thickness of the walls of the pericarp, its anatomical constitution remains the same. It is always formed of two membranes, the epicarp and the endocarp, and an intermediate bed of tissue called the mesocarp, sometimes thin and dry, at other times thick and succulent. Such is the constitution of the leaf from which it is derived, and of which it is only a peculiar modification.

This remarkable transformation of the leaves is not peculiar to fruits, for in more cases than is usually supposed, similar changes take place in the other floral organs. Thus the calyx is changed into a hard crustaceous body in Salsola and in Spinage; and is red and juicy in the Strawberry blite and Winter-green (Gaultheria), being in both instances commonly mistaken for the fruit from which it is wholly distinct. In the Yew, the bracts enveloping the seed become pulpy and berry-like. Nearly the whole bulk of the apple is a thickened calyx. The pulp of the Strawberry, as we have already intimated, is nothing else but the enlarged and juicy extremity of the flower-stalk or receptacle. Examples might be multiplied proving that all the appendages of the axophyte are subject to these transformations, which are erroneously imagined to be peculiar to the fruit.

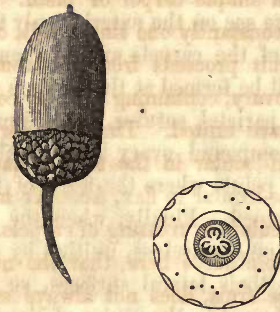
The fruit, like the pistil of which it is the final development, may be either simple or compound. The fruit is simple when

it proceeds from a simple carpel or pistil. In this case the pericarp presents constantly one single cell, or it is unilocular. The compound fruit proceeds from the compound pistil, the pericarp, like the ovary, containing as many cells as the number of pistils which have united. Thus the pericarp is bi-locular in the tobacco, tri-locular in the tulip, quadri-locular in the epilobium, quinque-locular in flax, &c. We have already made known these particulars in treating of carpels.

It is necessary to observe here, that the number of cells in the pericarp or ripe fruit, does not always exactly correspond to the structure of the ovary. It often happens, between the moment of fecundation and the maturity of the seed, that considerable changes take place in the internal structure of the ovary, a number of its dissepiments being absorbed during its progress towards maturity, so that an ovary originally multilocular becomes finally an unilocular fruit or pericarp. A great many of the Caryophyllaceæ and the Cistaceæ are in this case. The rapid increase of their ovaries break and efface their dissepiments, so that they are not found in the mature pericarp. Alterations take place, not only in the number of cells, but also in the seeds, the ovules being equally liable to become obliterated. In the acorn, (Fig. 92,) the young pistil is formed of three carpels, the ovary consisting of three cells with two ovules in each cell as represented in the transverse section. But the walls of the cells and five of the ovules are suppressed in the progress of development, so that the pericarp ultimately becomes unilocular and monospermal, or one-seeded. Hence the acorn or fruit of the oak (Quercus), consists of a one-seeded pericarp, surrounded by an involucre of bracts forming the cup or cupula.

Dehiscence of the pericarp. When the fruit has arrived at a

Fig. 92.



state of maturity, the pericarp opens to let the seeds escape. The fruits which open spontaneously in this manner are said to be dehiscent, (*dehisco* I gape). However, there are some fruits which fall to the ground without opening or dehiscing. The fleshy pericarps of the peach and apple for example, do not open; their seeds are liberated as the fruit decays. The dry pericarps of the Compositæ, the Maize, and the Ranunculus, remain indehiscent on the soil, enveloping the grain till the plantule in germinating forces a passage through them.

The pericarp, whether it proceeds from a single pistil, or from one that is compound, always presents on its outer surface longitudinal lines which are called sutures. One of these sutures, formed by the union of the free margin of each carpellary leaf, is called the ventral suture; the other, exactly opposite, and corresponding to its midrib, is named the dorsal suture; the former is generally connected with the axis, the latter with the periphery of the fruit. In a simple pericarp, such as the pod of the pea, for example, both these sutures are equally visible on the exterior of the fruit. But when the carpels solder together by their lateral surfaces, and form a

compound pistil, the ventral sutures are all united in the centre of the fruit, and we see on the exterior only the dorsal sutures. From this union of the carpels among themselves it follows, that new lines will be formed at their points of contact. These new lines called parietal sutures, are ordinarily seen on the exterior of the compound ovary between the dorsal sutures, and indicate the points where the walls of the several carpellary leaves are joined. Finally, when the carpellary leaves, instead of folding on themselves, uniting by their free margins and soldering by their lateral surfaces, so as to cause their ventral sutures to meet in the centre of the pericarp, and each folded carpellary leaf to form a distinct cell in its cavity; unite together by their margins, making only a slight introflexion towards the axis of the pericarp, in such a manner as to form a unilocular pericarp; the lines which result from this union are called marginal sutures. The nature and origin of these different sutures being understood by the student, he will find no difficulty in comprehending the several varieties of valvular dehiscence.

Dehiscence usually takes place in simple fruits either by the ventral or dorsal suture, or by both. Dehiscence takes place by the ventral suture in the pœony and Wild Columbine (Aquilegia); by the dorsal suture in the Magnolia; and by both sutures in the pea and Acacia.

When the fruit consists of several united carpels or is compound, the dehiscence may take place through the parietal sutures so as to resolve the fruit into its original carpels, as in the Colchicum, (Fig. 96,) when it is septicidal (*septum* a wall, and *cædo* I cut). This happens when the lamina of the carpellary leaves are only slightly united. When, however, these lamina are firmly soldered together dehiscence takes place by

Fig. 93.

Fig. 94.

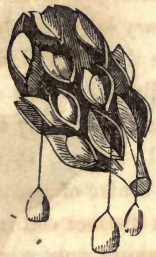


Fig. 95.

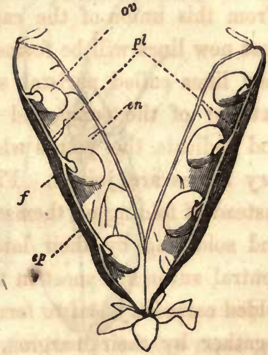


Fig. 93. The five carpellary leaves or follicles of Aquilegia, opening by their ventral suture.

Fig. 94. The carpels of Magnolia glauca with their dorsal sutures open and the seeds suspended from them by curious extensile cords.

Fig. 95. The legumen or pod of the pea, opening by both sutures at the same time. In the former instances the fruit was univalve, in this case it is bivalve. *ep.* Epicarp. *en.* Endocarp. *ov.* Ovules attached to the placenta *pl,* by means of the funiculus *f.* The legume opens by both ventral and dorsal suture. The placenta *pl* is double, and runs along each edge of the ventral suture. At the apex of the pod are seen the remains of the style and stigma, and at its base the remains of the calyx.

the dorsal suture, and the several lamina are detached from their midribs. The result of this is, that each of the valves carries on the middle of its internal surface a double lamina or dissepiment, which is composed of a portion of the united laminæ of the two different carpels, as in the Martagon lily. (Fig. 97.) This dehiscence is loculicidal (*loculus* a cell, and *cædo* I cut.)

In septicidal dehiscence each valve is a complete carpel, and generally contains the ovules attached to the placenta. In loculicidal dehiscence, however, sometimes the placenta accompany the dissepiments, as in the Pansy. Frequently,

Fig. 96.

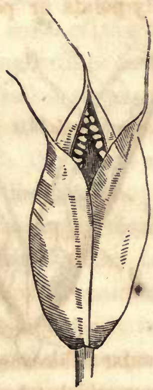


Fig. 97.

Fig. 97. Dehiscence of the three-celled fruit of the Martagon lily, showing the dissepiments in the middle of the valves.

however, the placenta and ovules remain firmly attached together, so that the dissepiments or united laminæ of the several carpellary leaves separate from their margins instead of midrib, which margins remain united and persistent in the centre of he pericarp, forming a sort of central axis or columella, as in the morning-glory (Convolvulus). Lastly, not only the margin but a part of the laminæ may be persistent about the central axis, so that when the pericarp opens at the parietal suture, the central column presents as many walls attached to it as there were dissepiments in the ovary before its dehiscence. We call this variety of loculicidal dehiscence, septifragal (*septum* and *frango* I break).

The sutures or seams of the pericarp, instead of dehiscing or splitting through their entire length, are sometimes only ruptured for a short distance from the apex as in the chickweeds,

(Cerastium.) In the snap-dragon, (Antirrhinum), the sutural rupture is so slight as to produce only points or pores in the upper part of the pericarp.

Fig. 98.

Besides these regular forms of valvular dehiscence there is a somewhat anomalous mode of rupture which takes place in a few plants, such for instance as the pimpernell (Anagallis), and henbane (Hyoscyamus), and which is called circumscissile, (*circum* around, *scindo* to cut.) The pericarp of these plants opens by a transverse circular line, following no sutures whatever but cutting directly across them. It is therefore an anomaly and not a true dehiscence, as we have employed the term. Fig. 98 is the seed vessel of the Hyoscyamus which is ruptured in this manner. The upper part of the pericarp separates like a lid from the lower part. This kind of fruit is called a pyxidium, (*pyxis* a chest.)

The pods of some Leguminous plants formed by a single carpel, are divided into several cells, either by the formation of false horizontal partitions, as in some Cassias, or by the contractions of the legume itself, as in Desmodium. Each of these cells contains a separate seed, and the pod when ripe separates by transverse dehiscence at these joints, and falls into pieces. This kind of pod is called a loment, (Fig. 99). This

Fig. 99.

Fig. 99. Loment of saintfoin (Hedysarum), which separates transversely into single seeded portions.

transverse disarticulation may be supposed to have some relation to a simply pinnate leaf, whose modification in this instance forms the carpel, the divisions indicating the points where the different pairs of pinnæ have united.

Different kinds of pericarps or fruits.—Several eminent botanists have attempted to make a classification of the different kinds of pericarps. We have not space for the enumeration of any more than those which most frequently occur, and to which reference is most generally made. The principal indehiscent fruits or pericarps are,

1. *The Caryopsis* or grain, (καρύα a nut, and ὄψις appearance.) This is a dry indehiscent one seeded pericarp, which is so incorporated with the seed as to be inseparable from it. It is seen in the cultivated grains such as maize, barley, oats, which in common language are called seeds, but which considered botanically are not seeds, but seed vessels containing a seed. It is only by examining them in their early state and noticing their styles, that we can become convinced that these grains are only apparent but not real seeds.

2. *The Achenium* (*a* without, and χαίνω I open), is a single seeded indehiscent fruit, the pericarp of which is distinct from the coats of the seed. The fruit of the Ranunculus consists of a number of these achenia borne on a convex receptacle. In the rose, the receptacle which supports them is concave and is

invested by the swollen and succulent fruit-like calyx. The fruits of the dandelion, sun-flower, and all Compositæ, are achenia or single-seeded pericarps. Each has been produced by a separate flower, and is provided with a persistent calyx the tube of which is closely united to the fruit, its limb forming a beautiful stellate down at the summit of the style or ovary, by means of which the achenium or mature ovary is lifted from off the surface of the broad and dilated receptacle and wafted by the winds to spots favorable to its germination. The bottom of the persistent calyces of the Labiatæ or mint family usually contain four achenia which look at first like seeds, and were actually regarded by Linnæus as such. He defines them as "semen tectum epidermide ossea," that is seed covered with an osseous epidermis, and hence he called the whole order gymnospermia, (γυμνος naked, σπερμα a seed.) The student may however easily satisfy himself that such is not the case, and ascertain that they are pericarps or seed vessels by cutting across them, when he will discover the true seed in their interior.

The Cremocarp.—This fruit is confined to the great natural order Umbelliferæ, of which the carrot and parsley are familiar examples. The Cremocarp (κρεμάω, to suspend,) is composed of two achenia, which are at first united to a common axis called the carpophore, (καρπὸς, fruit, and φορεω, I bear,) which axis separates at maturity, as in Fig. 100, the two achenia being placed apart and suspended from its summit. Each of these achenia is called a mericarp (μὲρος, part,) or hemicarp, (ημισυς, half, and καρπὸς, fruit.)

The Samara, (samera, seed of elm.) This is an achenium with a membranaceous appendage attached to its summit or margin, and forms those peculiar winged fruits suspended in

Fig. 100.

Fig. 100. Cremocarp of fennel (Fœniculum vulgare,) arrived at maturity, showing the carpophore and the two suspended mericarps or hemicarps.

bunches from the branches of the ash and maple, commonly known as keys. The fruit of the maple consists of two united Samara.

The Pome, (*pomum,* an apple.) This is a fleshy indehiscent fruit with a superior calyx, which is therefore adherent to the ovary. In the mature pome, the epicarp and calyx are blended together and form along with the mesocarp the thick cellular and edible part of the fruit, whilst the endocarp enveloping the seeds in its interior takes the consistency of parchment, and usually forms five cavities in the centre of the fruit.

The Drupe.—This is a thick, fleshy and indehiscent fruit, containing an unilocular nut, as in the plum and cherry. This nut is formed by the ossification of that portion of the pericarp which is called the endocarp, which in this case forms a strong stony envelope around the seed. In drupaceous fruits, such as the peach and cherry, the epicarp, mesocarp, and endocarp are easily distinguished and separated, but in the nut these parts are all so much ossified and blended together as to be indistinguishable. The nut only differs from the drupe in being a less succulent and more coriaceous

pericarp. The fruit of the raspberry and blackberry is an aggregate of little drupes borne on a common receptacle.

The Bacca, or berry. This is a fleshy, compound fruit, which is pulpy throughout. This name usually distinguishes such fruits as the gooseberry and currant, in which the calyx is adherent to the ovary and the parietal placentas. The seeds are at first attached to the placentas, but as the fruit ripens they become detached from the placentas, which finally form that pulp which fills the interior of the berry and in which the seeds are imbedded. The term berry is in general applied to all pulpy fruits.

The principal varieties of the dehiscent pericarp are—

1. *The follicle* (folliculus, a little bag.) This is an unilocular fruit, opening longitudinally by a single suture, the *ventral,* into one valve, which represents an open carpellary leaf. The seeds are attached to a simple sutural, or bi-partite placenta, and sometimes become free at the moment the valves separate. Follicles are very seldom solitary fruits. They are usually aggregated on a short receptacle, and form a verticil, as in the Columbine,

2. The legume or pod (*Legumen,* pulse), is a dry fruit, bi-valve, opening at the same time by the ventral and dorsal suture, and bearing its seeds on the former. In the bladder senna (Colutea arborescens), the legume is inflated, and retains its leaf-like character. Fig. 90 is a lomentaceous variety of the legume to which reference has been already made, and which breaks up at the constrictions. This fruit belongs to all the family of the Leguminosæ of which it forms the principal character. Examples—the pea, bean, and the acacia.

3. *The capsule* (*capsula,* a little chest.) This is a general name for all dry and dehiscent fruits which open by valves or

Fig. 101.

Fig. 101. The Siliqua of the Wall Flower (Cheiranthus cheiri) opening by two valves from the base upwards. The two placentas bearing the seeds on their surface, remain in the middle of the fruit, with a replum between them.

pores. It is easy to imagine from this, that the forms of the capsule will be exceedingly variable. The porous capsule is seen in the poppy, which is a seed vessel of a woody texture, proceeding from a compound ovary, and dehiscing by chinks which may be seen in the dry fruit, just beneath the overhanging surface of its numerous radiating stigmas. Two other varieties of the capsule are worthy of a particular notice.

4. *The Siliqua* (*siliqua* a husk or pod.) This is a pod-shaped capsule, the peculiar fruit of Cruciferous plants, composed of two carpels which open as valves from below, upwards. The parietal placenta, before the period of dehiscence, having been united together by a plate of cellular matter termed the replum, which forms a false septum across the cavity of the ruit, separate from the valves, when these open and remain

attached to the replum, in the axis of the fruit. These placenta thus united together by the replum, frequently remain after the fall of the valves, until the foliage of the plant finally decays.

Fig. 102.

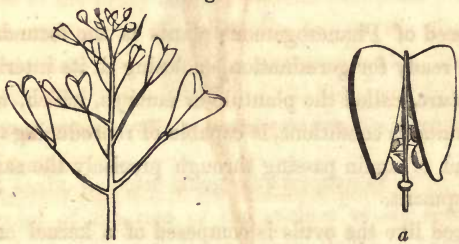


Fig. 102. The fruiting branch of the Shepherd's purse (Capsella bursa pastoris,) supporting siliculæ. *a.* Magnified silicula, opening by two valves from the back upwards, each valve leaving its placenta covered with seeds, and attached to the replum in the centre of the fruit.

5. *The Silicula.* This is simply a short and broad Siliqua containing sometimes only one or two seeds. It is also peculiar to Cruciferous plants.

CHAPTER XVI.

THE STRUCTURE OF THE SEED.

The seed of Phanerogamous plants is the fecundated ovule ripe and ready for germination, enclosing in its interior a plant in miniature, called the plantule or embryo, which, when there are the suitable conditions, is capable of reproducing the mother plant, and of again passing through precisely the same phases of development.

The seed like the ovule is composed of a kernel or nucleus, usually covered by two cellular integuments, and included under the general name of episperm.

The episperm or proper tegument of the seed is the coat which covers it exteriorly. This coat is formed by the two membranes which we have seen to exist in the ovule at the moment of fecundation, viz., the primine and secundine. In a great number of cases these two membranes are so soldered together that the episperm is thin and constitutes only a simple membrane. But it sometimes happens that the two superposed membranes of the episperm are distinct enough; and when this is the case the exterior membrane is ordinarily more thick and tough than the interior one, immediately enveloping the seed. To distinguish them from each other, the former is called the testa, and the latter the tegmen. These two membranes are perfectly distinct in the episperm or seed coat of the Castor oil plant (Ricinus.)

The episperm has usually, on its exterior surface, certain markings which correspond to those mentioned in the ovule.

On one part of the surface of the episperm we see constantly the hilum, a scar marking the point by which the seed was attached to the funiculus or placenta whilst in the pericarp (Fig. 103.) *a*. The hilum is more or less conspicuous on the epis-

Fig. 103.

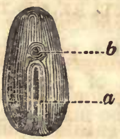


Fig. 103. Leguminous seed. *a*. The hilum under the form of a linear cicatrice. *b*. The micropyle.

perm of all seeds, its color being very frequently quite different from the color of the rest of the surface of the seed. The hilum is very conspicuous in the bean and pea, being quite black in the former. It is by the hilum that the nourishing vessels of the pericarp penetrate the seed. They traverse the double or single membrane of the episperm, and enter the nucleus or kernel by the chalaza, a term applied to the fibro-vascular bottom of the nucleus or kernel where it unites with the episperm.

On the surface of the episperm, we perceive frequently very near to the hilum or in a point diametrically opposite to it a punctiform opening extremely small which is called the micropyle. (Fig. 103.) *b*. The micropyle is simply the foramen or opening of the two membranes of the ovule which is contracted to a point, so as to become sometimes hardly perceptible. The micropyle may be readily detected in the pea or bean in the form of a small hole or point which in this instance is near the hilum. The micropyle always corresponds to that point of the nucleus where the embryo sac is formed, and the summit of which gives birth to the embryonic vesicle. It follows from

this that the radicle of the embryo always points to the micropyle. This fact the student may readily ascertain by dissecting any seed which has a visible micropyle on the episperm, and ascertaining the direction of the radicular extremity of the embryo. He will find it invariably pointing to this very spot.

Sometimes the micropyle entirely disappears from the surface of the episperm. Its place, however, may be readily ascertained. If the skin of a seed be carefully examined it will be usually found to be marked with lines or bands which run upwards from the hilum. These lines always converge and meet in the micropyle, so that by following them with the eye, the micropyle may be frequently discovered on the episperm, when owing to its minuteness it would otherwise escape detection.

The chalaza is more or less visible in all anatropous seeds, being often colored and of a denser texture than the surrounding tissue. At the apex of the seed of the orange and many other plants, it may be perceived on the episperm in the form of a large brown spot. In orthotropous and campulitropous seeds the chalaza is directly superposed on the hilum, with which it is immediately confluent, but in all anatropous seeds it is placed apart from the hilum, and is connected with a vascular bundle called the raphe, which forms a longitudinal prominence more or less conspicuous on the episperm. In most plants the raphe consists of a single line, as in the castor-oil plant, but in the orange and lemon it ramifies upon the surface of the episperm. Fig. 104.

It is proper to remark here, that the terms orthotropous, campulitropous, and anatropous, employed to designate the different kinds of ovules, are equally applicable to seeds, all seeds occurring under one or other of these three leading forms.

Fig. 104.

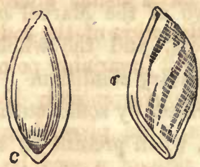


Fig. 104. Anatropal seed of the Orange, (Citrus aurantium,) opened to show the chalaza, *c*, which forms a brown spot at one end; *r*, raphe, or internal funiculus ramifying in the rugose or wrinkled testa of the orange.

On the outside of the episperm there is sometimes an additional envelope formed, after the fertilization of the ovule, by an expansion of the funiculus at the hilum. This funicular expansion, which covers more or less of the surface of the episperm, is termed an aril. The aril is very conspicuous in the Spindle tree or Burning bush, (Euonymus,) where it forms a beautiful scarlet envelope to the seed. The tough, fleshy and lacerated body which invests the seed of the nutmeg, known in commerce under the name of mace, is an aril.

The nucleus, or kernel. This is all that part of the ripe seed which is enveloped by the episperm. It is formed by the development of the nucleus of the ovule, and like that organ is attached to the episperm by its base, which forms the chalaza. Generally, in the ripe seed this communication is destroyed. The kernel in a fecundated seed always contains an embryo.

In exalbuminous seeds, after fecundation, the embryo takes a considerable development, absorbing into its cotyledons the nutritive matter of the nucleus, so as ultimately to constitute the entire kernel, as in the pea and bean. In albuminous seeds, the embryo appears to be arrested in its growth whilst yet in a minute and rudimentary condition, developing only so

far as just to exhibit its component organs, and remaining imbedded in the nutritive matter of the nucleus which is unabsorbed. The embryo of the Marvel of Peru, (Mirabilis,) of the maize, buckwheat, and the whole of the cerealia continues in this rudimentary condition.

The albumen, termed by some authors the perisperm, and also the endosperm, when present in the kernel varies in its consistence according to the nature of the deposit and the state of the cells. It consists of a mass of cells without any appearance of vessels, which may be thin and dry and contain a great quantity of fecula or starch, as in the corn and the other grasses; or thick and fleshy, containing juices of various kinds, as in the cocoa-nut and Euphorbiaceæ; or finally, the cells may be of a horny or ligneous nature, as in the coffee and vegetable ivory, (Phytelephas.) The quantity of albumen in seeds depends on the extent to which embryonic development is carried. When the embryo is small the albumen is abundant, as in the seed of the monkshood, (Aconitum,) Fig. 105, where *e* repre-

Fig. 105.

Fig. 106.

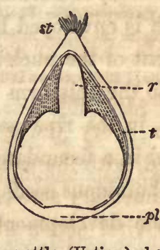


Fig. 106. Vertical section of the achenium of the nettle, (Urtica,) showing the embryo nearly filling the achenium, *r* radicle; *pl* plumule; *t* testa, or integument.

sents the embryo. When the embryo is large, as in the nettle, Fig. 106, the albumen is very scarce. In the Labiatæ, the

albumen is reduced to a mere pellicle by the great development of the embryo.

The embryo is the most important part of the seed, and the final product of the vegetative functions. When this is formed, and the seed is fully ripe, a pause in growth takes place, and the embryo which is the future plant in the first stage of its development, will sometimes remain for a long time in an apparently dead condition enveloped in the folds of the seed, until suitable circumstances arouse its dormant vitality. The embryo is a complete plant in miniature, and therefore offers the same general disposition of its parts as that which we have already noticed in the adult plant. Thus we distin-

Fig. 107.

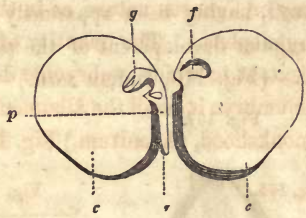


Fig. 107. Embryo of the Pea (Pisum,) laid open to show its different parts. This embryo occupies the whole interior of the seed. *c, c,* its two fleshy cotyledons; *p,* the plumule; *r,* the radicle; *g,* the gemmule; *f,* the depression left by the gemmule in the cotyledon. This embryo is dicotyledonous and hypogeal, the cotyledons remaining below, during germination.

guish, in every young plantule, an axophyte more or less developed, with the usual appendages, root, stem and leaves, all in a rudimentary state, and all manifesting an identity in their incipient vital action with the same phenomena in the adult plant. The little embryo axophyte commences to develope at its two extremities in two opposite directions, and puts forth laterally its rudimentary leaves; that portion which ascends is called the plumule, that which descends the radicle; the

rudimentary leaves are named cotyledons, and the little bud by which the plumule is terminated, is called the gemmule, (Fig. 107.)

Before we examine in succession these four parts of the embryo, let us consider their relative positions with respect to the other parts of the seed.

When albumen is present in the seed along with the embryo, the embryo may either lie in its midst directly in the axis of the seed as in the pansy, Viola tricolor, (Fig. 108,) when it is axial; or it may surround the albumen itself, instead of being surrounded by it as in the Marvel of Peru, (Fig. 109,) when it is peripherical. In the grasses, maize, wheat and all the cerealia, the embryo lies external to the albumen on one of the sides of the seed, having been apparently forced into this position by the irregular development of the parts of the seed, when it is abaxial. (Fig. 110, Indian corn.)

Fig. 108.

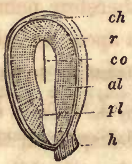


Fig. 109.

Fig. 110.

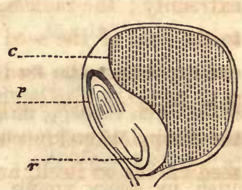


Fig. 108. Vertical section of the seed of the Pansy. The seed is anatropal; the embryo homotrope. *ch*, chalaza to which *co*, the cotyledons point; *pl*, the plumule; *h*, the hilum; *al*, the albumen surrounding the embryo which it will be perceived is axial; *r*, the raphe connecting the hilum or base of the seed with the chalaza or base of the nucleus.

Fig. 110. Vertical section of a grain of Indian corn (Zea Mays,) *r*, the radicle; *p*, the plumule; *c*, the cotyledons.

The embryo is sometimes straight but very frequently curved in a variety of ways, its curvature depending on that

of the seed. In orthotropous and anatropous seeds the embryo is usually straight; in such seeds as are campylotropous it is curved. Whatever may be the form of the seed, the radicle always points to the micropyle and the cotyledons to the chalaza or some point in its vicinity. This important law being remembered, it is only necessary to ascertain the situation of the micropyle with respect to the chalaza on the surface of the episperm, and the character not only of the seed, but the exact position of the embryo within its folds is at once determined without any further trouble. Thus in the orthotropous seed of the nettle, (Fig. 106,) we know that the micropyle is directly opposite to the hilum and chalaza, which is the base of the seed, the radicle therefore points to the apex of the seed, and its plumule to the base, and the embryo is antitrope (*αντί*, opposite, *τρέπω*, I turn,) or inverted. But in anatropal seeds, as in the pansies, (Viola tricolor, Fig. 108,) we see on the surface of the episperm the micropyle close to the hilum or base of the seed and the chalaza at its apex or opposite extremity; the radicle or base of the embryo therefore points to the base of the seed and its cotyledons to the apex, and the embryo lies in the seed in its natural position; that is to say, it is erect or homotrope, (*ὅμοιος*, like, and *τρέπω*, I turn.) In the campylotropal or curved seed, the base is not displaced, the seed curves on itself, and the micropyle approaches the hilum and chalaza, which is still confluent with it; from this we know that the cotyledonary and radicular extremities of the embryo also approach each other, or the embryo is amphitrope (*ἀμφὶ*, around, and *τρέπω*, I turn), or follows the curvature of the seed, (Fig. 109.)

Let us now examine in particular each of the parts which constitute the embryo.

Fig. 111.

Fig. 111. Vertical section of the campulitropous seed of the red campion (Lychnis,) showing the curved embryo.

1. *The radicle.*—This constitutes the lower extremity of the embryo, which in developing forms the root, or which gives birth to it. It appears very often under the form of a little round or conical teat. This, by germination, sometimes elongates and becomes the body of the root. Its extremity continues naked and afterwards divides. This mode of development, which is characteristic of Phanerogamous plants having two seed-lobes or cotyledons, is termed exorhizal, (ἔξω outwards, and ῥιζα a root.) At other times the radicle in germinating, after having taken a certain degree of elongation, stops the teat at its extremity, becomes covered with a cellular layer as with a sheath, through which breaks forth one or more fibres, which constitute the true roots of the embryo. This kind of development, which is peculiar to such phanerogamous plants as have only one seed-lobe, is termed endorhizal, (ἔνδον within,) and the sheath formed at the extremity of the radicle teat is called the coleorhiza, (κολέος a sheath, and ῥιζα a root. Fig. 112, shows both kinds of germination.

The plumule forms with the radicle the axis of the embryo. It is developed after the radicle, which it surmounts, and with which it is united. It exists only in Dicotyledonous embryos, and is terminated at its summit by the gemmule. It is the plumule which, by its development, produces the stem. It commences from the point where the cotyledons are attached

Fig. 112.

Fig. 113.

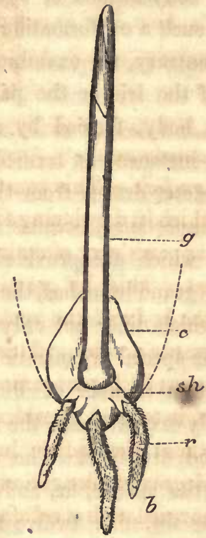


Fig. 112. *a* shows the exorhizal germination of the Dicotyledonous seed of the orange; *c*, the cotyledon; *g*, the first pair of aerial leaves; *r*, the radicle naked and without a sheath.

Fig. 113. Seed of oats sprouting.' *r*, roots passing through the sheath, *sh*, from the single cotyledon *c*. *g*, The young leaves and stalk.

to it, and which it raises with it above the earth, when its elongation operates from its base.

The cotyledons.—These are the lateral appendages of the embryo axophyte. The cryptogamia have no cotyledons in their embryos, which are therefore acotyledonous. The embryo in such cases is called a spore, and as it gives off roots indifferently from any part of its surface, and from a fixed point, it is termed heterorizal, (ἕτερος diverse.) Plants possessing cotyledons in their embryo are termed cotyledonous. If we examine

the embryo of the bean, the pea, or the oak, we shall see a cotyledonary body formed of two cotyledons. The embryo which presents such a conformation is a Dicotyledonous embryo. If, on the contrary, we examine the embryo of the wheat or the maize, of the iris or the palm, we shall find a simple cotyledonary body, formed by a single cotyledon. The embryo in this instance is termed a monocotyledonous embryo. The character drawn from the number of cotyledons is of the highest importance, because it divides all phenogamous plants, or those which are provided with flowers properly speaking, into two grand branches, the Monocotyledons and the Dicoty ledons, which differ not only in the structure of their embryo, but in the special organization of all their other parts.

A certain number of Phanerogamous plants are, however, apparently exceptions in the structure of their embryo to these two grand divisions. The cone-bearing plants, for example, such as the spruce, fir, and larch, have not one or two, but sometimes six, nine, twelve and even fifteen verticillate cotyledons, which resemble in their linear form and verticillate arrangement, the clustered and fascicled leaves of the larch. To such embryos the term polycotyledonous has been applied, but M. Duchatre has proved that these polycotyledonous embryos are only Dicotyledonous embryos, whose two cotyledons are deeply divided into a number of segments. Therefore, it is proper to retain them among the Dicotyledonous embryos of which they are only a variety.

In exalbuminous embryos, that is to say, those which are immediately covered by the episperm or seed coat, the cotyledons are excessively thick and fleshy, and their albuminous contents furnish to the young and germinating embryo the first materials of its nutrition. In such seeds as are albumi-

nous, on the contrary, the cotyledons are thin and membranaceous, retaining in a great measure the appearance of leaves, in the midst of the surrounding albumen.

At the period of germination the cotyledons separate from the integuments of the seed, and either appear above the ground, different in form from the other leaves of the plant, or they remain hidden in the earth without showing themselves, as in the pea and the horse chesnut, until they finally decay. In the former case, they are epigeal (ἐπὶ upon or above, and γέα the earth;) in the latter case they are hypogeal (ὑπὸ under.)

The gemmule, is the little bud at the summit of the plumule. Like all other buds, it is composed of a little axis continuous with that of the embryo, and certain minute rudimentary leaves which represent the first leaves which the embryo is going to develope. In general, in Dicotyledons the gemmule is placed between the two cotyledons, which in being applied one against the other, cover and hide it completely. It is therefore necessary to separate the cotyledons in order to see the gemmule. In Monocotyledons embryos, the plumule is absent and the gemmule is placed within the sheathing base of the cotyledonary leaf, and situated as it were, on one of its sides. In developing, the gemmule gives birth to the aerial portion of the stem, and its unfolding rudimentary leaves soon take in succession the form, position and size of those leaves which are peculiar to the adult plant.

CHAPTER XVII.

ON THE DISPERSION AND GERMINATION OF SEEDS.

It must be obvious that the immense quantity of seed which plants generally produce, could never germinate in their immediate neighborhood, and therefore, as the seed ripens, the pericarp gradually assumes such an organization as is calculated to effect its dispersion or removal to a more distant locality. The dissemination of the seeds is the result of the peculiar organization of their pericarp or seed-vessels, rather than of the seeds themselves, which in this respect present some of the most interesting and beautiful contrivances in nature.

Sometimes the pericarp opens elastically with a spring-like mechanism, and discharges the seed contained in its cavity to a considerable distance. The seeds of the castor oil plant, of the common garden balsam, and of the common furz, or whin-bush of Europe, are separated from their pericarps in this manner. In Hura crepitans, a plant which grows in the West Indies and in South America, the seeds are projected from the strong bony envelope of the pericarp as soon as it opens, which it does with immense force and with a report as loud as a pistol.

The pericarps of the thistle, dandelion, and other species of Compositæ, have attached to them a beautiful stellate down; contrivances which are evidently intended to catch the wind, and by means of which they are removed when fully ripe from off the surface of the receptacle of these plants, and wafted to a distance to spots favorable to their germination. The pericarps to which these appendages are attached, will sometimes

travel for miles until a shower of rain or a humid atmosphere causes the tuft to collapse, when the pericarp falls to the ground. In some instances, as in the thistle, this down projects directly from the surface of the pericarp like the feathers of a shuttle-cock; in the dandelion and goatsbeard it is supported upon a stalk which elevates it above the seed. In the last plant each fine hair of the tuft is itself a feather, forming altogether one of the most elegant and perfect objects.

In other species the pericarps are furnished with hooked hairs, which cover their entire surface, as in galium and burdock, by means of which they cling to the bodies of men and animals, and are thus scattered far and wide. In autumn it is impossible to traverse the woods or marshes without having such pericarps forced upon our attention. The achenia of Bidens bipinnata, or the Spanish needles, are especially troublesome. The achenia of this plant are surmounted with three or four persistent awns, which are downwardly barbed, and by means of which they very readily adhere to the dress of the traveller. How little are persons aware when they brush off these troublesome intruders, in some distant locality to which they have unwillingly carried them, that they are fulfilling the grand and secret purposes of nature!

Occasionally, as in the Asclepias or milkweed, and the Epilobium or willow-herb, the seeds themselves are furnished with the coma or tufts of hairs, by means of which, on the dehiscence of the pericarp, they are lifted by the wind out of its cavity and carried away sometimes to a great distance from the parent plant.

Birds, too, are important agents in the diffusion of seeds. It is well known that the seeds of numerous berries and small fruits will grow, though they have passed through the bodies

of birds. It is in this way that Phytolacca decandra, or the common pokeweed, appears to have been dispersed over the whole of North America. The berries of this plant are eaten by the robin, the thrush, the wild pigeon, and many other birds, which thus carry them hundreds of miles from the plant which produced them. In this manner we can account for a fact which every practical botanist and observer of nature must have noticed, viz.: the sudden appearance of a single plant in a place where its species was entirely unknown before.

Some pericarps are conveyed by the rivers into which they fall, or by the waves of the ocean, many hundreds or thousands of miles from the countries which originally produce them. In this manner many of the native plants of France, Spain, and other adjacent countries, have been naturalized in England; and the pericarps of tropical climates are conveyed to the coasts of Norway and Scotland. The foreign pericarps which are annually left on the Norway coast, are principally cashew-nuts, bottle-gourds, cocoa-nuts, and the fruit of the dogwood tree. These are often in so recent a state, that they would unquestionably vegetate were the climate favorable to their growth and existence. When carried to countries better suited to their nature, they germinate and colonize with a new race of vegetables the land on which the ocean has cast them. In this manner it is that the coral islands, as soon as they appear above the waves of the Pacific, are speedily covered with a crop of luxuriant vegetation. The cocoa-nut is well adapted for this purpose, as it grows luxuriantly in salt water, and it is probably the first arborescent species which vegetates on these newly-formed lands.

Most of the seeds thus carried abroad never germinate at all, as they either fall into situations unfavorable to their

growth, or upon a soil which is already pre-occupied by other plants. All the plants of a given district may be regarded as at war with each other. The arborescent species prevent, by the extent of soil which they occupy, the vegetation of species of a humbler growth. Each has to struggle into existence against a host of competitors, for nature, although she has been prolific of the seeds of life, has limited the supply of room and food. A number of ferns, for example, which may be growing on a hill-side, will, by their pre-occupation of the soil, successfully maintain their ground against all other intruders for ages, notwithstanding the facilities afforded to other plants for the dispersion of their seeds. If any chance seed should be borne to this spot by any of the agencies which we have enumerated, or by other causes, it cannot germinate among them, as they absorb all the food from the soil.

The seeds which have been thus unfavorably located, retain their vitality for a longer or shorter period of time. Such as have very thin and delicate integuments, will lose their germinating power after a few weeks' exposure; so also oleaginous seeds will in general, decay much sooner than such as contain albumen. Other seeds, on the contrary, will retain their vitality for an indefinite period of time. This is the case with the Leguminous plants, the seeds of which may be kept for years without any material detriment to their germinating power. Peas taken from the herbarium of Tournefort, where they had remained for more than one hundred years, were made to germinate in the botanical gardens at Paris. Those changes by which the ovule is changed into the mature seed, appear to be all made with a special reference to any mishaps which may befall it when thrown on the charity and care of nature by the parent plant, as well as to provide it with a

store of nutriment on which it may subsist during the early stages of its development.

When the plant approaches the close of its allotted period of life, it is surprising with what care provision has been made for the continuation of the species, as if nature had determined to secure it, if possible, an immortality of existence upon the earth's surface. Hence not only the beautiful contrivances to effect the removal of the seed to spots favorable for its germination, but also the immense quantity of seed which the dying plant produces. On a specimen of the castor oil plant, which the author cultivated in his garden, he counted ten clusters of pericarps, or seed-vessels; each cluster produced upwards of fifty pericarps, and each pericarp contained three seeds. The total number of seeds produced by the plant was, therefore, $10\times50\times3=1500$. Each of these seeds, be it remembered, contained within its folds an *incipient* repetition of the parent plant in the form of a young embryo. Supposing each seed to germinate, and the plants to arrive at maturity, the product of the next season would be $1500\times1500=2{,}250{,}000$ seeds! In other plants, the first crop of seeds is still greater. It has been calculated that the sunflower produces 4000 and a single thistle 24,000 seeds the first year; therefore the second year's crop would amount to 16,000,000 of seeds in the former, and 576,000,000 of seeds in the latter instance. How immense the amount of vegetable life which may spring from a single seed! Happily for mankind, every vegetable embryo is not destined to give rise to a future progeny. Millions of seeds, or vegetable embryos, are called into existence, but their incipient life is speedily destroyed by a variety of causes. Were it not for the operation of these causes, by which the species is kept within prescribed limits, such is the fecundity

of nature, that there can be no doubt that the seed from a single thistle or dandelion would, in the course of a few years, be sufficient to cover with plants not only every square inch of the superficies of our own world, but the entire surface of every other planet in the solar system.

But although nature has been thus careful to ensure a repetition of their beautiful and evanescent forms, all plants multiply within prescribed limits, which they cannot pass. Fecundity is therefore no barrier to the variety which everywhere prevails, which is the principal charm of the vegetable creation, and from which we derive so much instruction in the study of their individual forms.

When, however, the seed falls into a soil favorable to its germination, it will grow and become a plant, running through all the phases of the vegetation of its predecessor.

We have only now to lay before the student the conditions which are necessary to germination, and the interesting series of phenomena connected with the evolution of the young plantule from its integuments.

The exterior agents indispensable to germination are water, air, and heat.

Water is necessary in germination as in all the other phenomena of vegetable life. It penetrates into the substance of the seed, softens its envelopes, and makes the embryo swell. It therefore places the seed in the conditions which are most favorable for its development. As soon as germination commences, it dissolves the dextrine and the other soluble principles which exist in the seed, and which are formed by the transformation of the starch, and conveys these nutritive materials to the young embryo.

Air as well as water is also necessary. Experiments show

that seeds will not germinate *in vacuo*, or in a space from which the air has been artificially removed. Hence seeds buried too deeply in the soil will not germinate, as the air cannot get access to them, but if by any natural or artificial causes they are brought into the superficial beds, germination very soon commences. It is thus that we see suddenly appear in a locality certain plants which did not grow there before, as for instance, when a waste field is cultivated.

It is the oxygen of the air which acts principally in germination; for seeds plunged in pure nitrogen or hydrogen neither germinate nor develope. It is by the absorption of oxygen that the starch which remains in the nucleus, or which has been absorbed into the cotyledons, is rendered soluble and nutritive.

It is well known that starch is quite insoluble in cold water. By what remarkable operation in vegetation does it become soluble, so as to be dissolved and transported to all parts of the plant? This question we now proceed to answer. Starch is profusely spread through all the organs of the plant, and is accumulated especially in the seed, as a store of nutriment on which the young embryo subsists, until such times as its roots and leaves are sufficiently developed for the accumulation of its proper food from the earth and atmosphere. But in order to its assimilation by the young embryo it is necessary that the starch in the cotyledons or nucleus should be rendered soluble. When the temperature and other conditions are favorable, a vegetable secretion termed diastase forms itself in all the cells which contain starch. This diastase possesses the singular property of transforming starch into a soluble gum termed dextrine, which the water is able to carry to all parts of the plant. The action of the oxygen of the air, through the secretion of the diastase, having thus changed the starch

to dextrine, and the continuation of the same process converting some dextrine into sugar, which being dissolved by the water, also penetrates all the parts of the embryo, thus induces the necessary nutritive and germinating processes.

The starch contained within the folds of the seed, is therefore at the end of a certain time, completely re-absorbed. This disappearance of the starch is the result of its combustion by the embryo, or of its slow conversion principally into carbonic and other vegetable acids, and in part into cellulose.

Heat is therefore evolved during germination, and a certain amount of it becomes indispensable to the vital action of the seed. Placed in the midst of a temperature below zero, it remains benumbed and stationary even under the influence of air and humidity. But a mild temperature accelerates the development of all the phenomena of vegetation. Hence it is that the gardener is accustomed to hasten the development of such exotic grains as it is his interest to cultivate, by sowing them in a hot bed, and by consequence surrounding them with a humid and artificial heat. But it is necessary that this temperature does not pass certain limits, otherwise, so far from hastening the development of the seeds, it will dry up and destroy the principle of life within them.

The degree of heat required to excite the vitality of the embryo, varies from 50° to 80° (Fahrenheit,) for the plants of temperate climates. The seeds of tropical plants require a much higher heat to call them into action, varying from 90° to 110° (Fahrenheit,) and occasionally a more elevated temperature than even this, is found to be necessary.

Light exercises an unfavorable influence on germination. This must necessarily be its effect on the germinating seed, for we have shown that the absorption of the carbonic acid of the

atmosphere, the assimilation of the carbon and the evolution of the oxygen, are processes which are greatly forwarded by this agent. Now all these processes are just the reverse in germination, for oxygen is absorbed and carbonic acid is eliminated. It is not true that seeds will not germinate unless protected from the influence of light, since every day we see plants germinating very well and with considerable rapidity, on fine sponges, on sand, or other bodies from which they can imbibe water; but it is nevertheless true that a strong light will greatly retard whilst darkness will favor the germinating process.

The general phenomena of germination may be thus summed up. When there are the suitable conditions of temperature, air and moisture, the first phenomena which we observe in the germinating seed is the swelling and softening of the envelopes which covered it. These become distended with moisture, and ultimately ruptured in a more or less irregular manner, as the swelling of the seed increases. About the same time that the seed commences to be distended with moisture, it attracts oxygen from the atmosphere. This oxygen induces the formation of the diastase, which acts on the starch contained in the cotyledons, converting it into dextrine and sugar, which dissolved by water, are conveyed to all parts of the young embryo. The bulk of this sugar is converted into carbonic acid, whilst the remainder or dextrine, is organized into cellulose. Therefore, instead of taking in the materials of nutrition from the earth and atmosphere, or assimilating externally in germination as in the process of flowering, the plant consumes these materials or assimilates its own products. Now all the organs of plants, whatever be their form, their nature, or their destination, have for a base the same immediate principle, cellulose; but starch,

dextrine and sugar have precisely the same chemical composition as cellulose. Thus it is, that the store of nutritive, though unassimilated and insoluble starch, with which the seed is so copiously provided, is by the forces of nature rendered soluble, and converted into dextrine, sugar, and finally cellulose, the substance which constitutes the very basis of all the vegetable tissues, it becomes the source from whence the embryo derives the materials of its nutrition and increase.

These chemical changes in the substance of the seed soon awaken its dormant vitality. We see the radicle of the embryo descend through its swollen and ruptured integuments into the earth, whilst at the same time the plumule rises into the atmosphere, carrying up with it the young cotyledons, which soon unfold in the form of two white and opposite leaves above the earth's surface. Exposed to the action of light we see them gradually change their color, chlorophyl being deposited in their superficial cells. The cotyledons appear to be only indifferently adapted to the aerial medium into which they are elevated, and hence, as we have seen, they sometimes continue below the ground without any detriment to the growth of the young embryo. When, however, the gemmule or bud at the summit of the plumule elongates and the true and permanent leaves of the plants appear, they perform the functions of aerial leaves in a much more perfect manner; at the same time, from the other extremity of the axophyte, additional roots are developed, and the organs at both extremities are beautifully adapted to their respective media. Germination is now completed, the cotyledons and other appendages of the embryo decay and disappear, having performed their respective functions, and the young plantule, rejoicing in all

the freshness and beauty of vegetable youth, developes into the earth and atmosphere and depends for its future supplies of food on its leaves and roots, running through precisely the same phases of vegetation as its predecessors.

THE END.

the embryo and young of vegetable plants, develops into the earth and atmosphere and depends for its future support at last on its leaves and roots, running through precisely the same phases of vegetation as its predecessors.